

# Evaluation of SiC Heating in a Microwave Field



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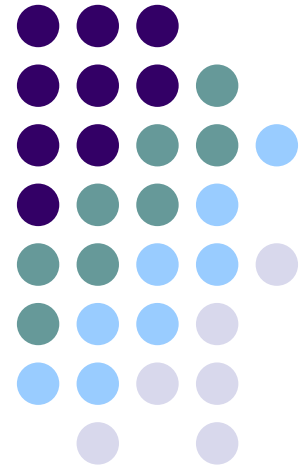
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Rutgers University

David Laughton, James Funk

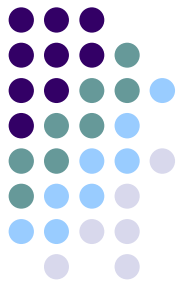
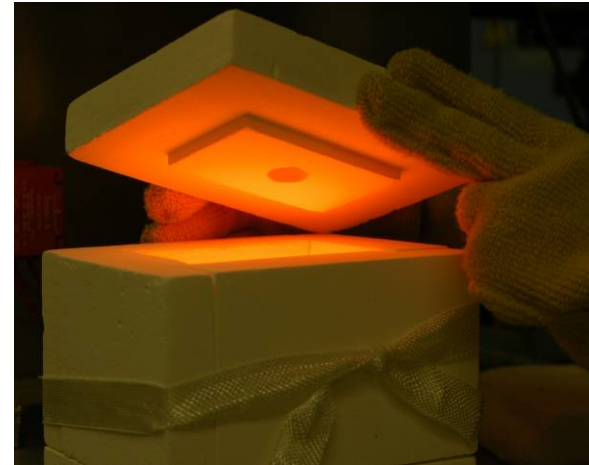
Superior Graphite

**January 28, 2010**

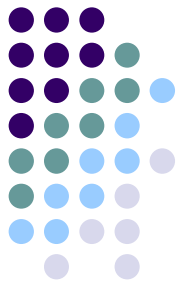


# Outline

- Microwave SiC - Goal
- Background Info
- Microwave Study Results
- Conclusions
- Future Work



# SiC- Microwave Potential



## 1) Finer grain size

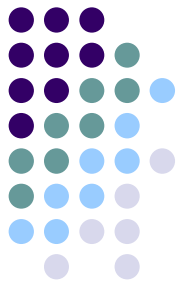
- Property improvements

## 2) Efficient process

- Low energy, less time, pressure-less
- Allow for complex shapes

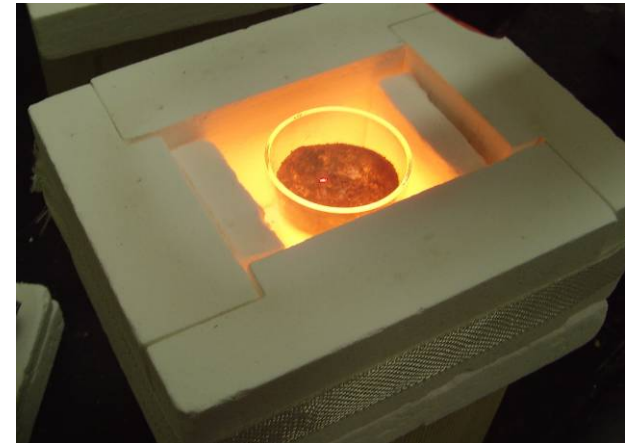
# Background

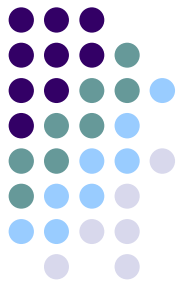
## Microwave Sintering SiC



Need:

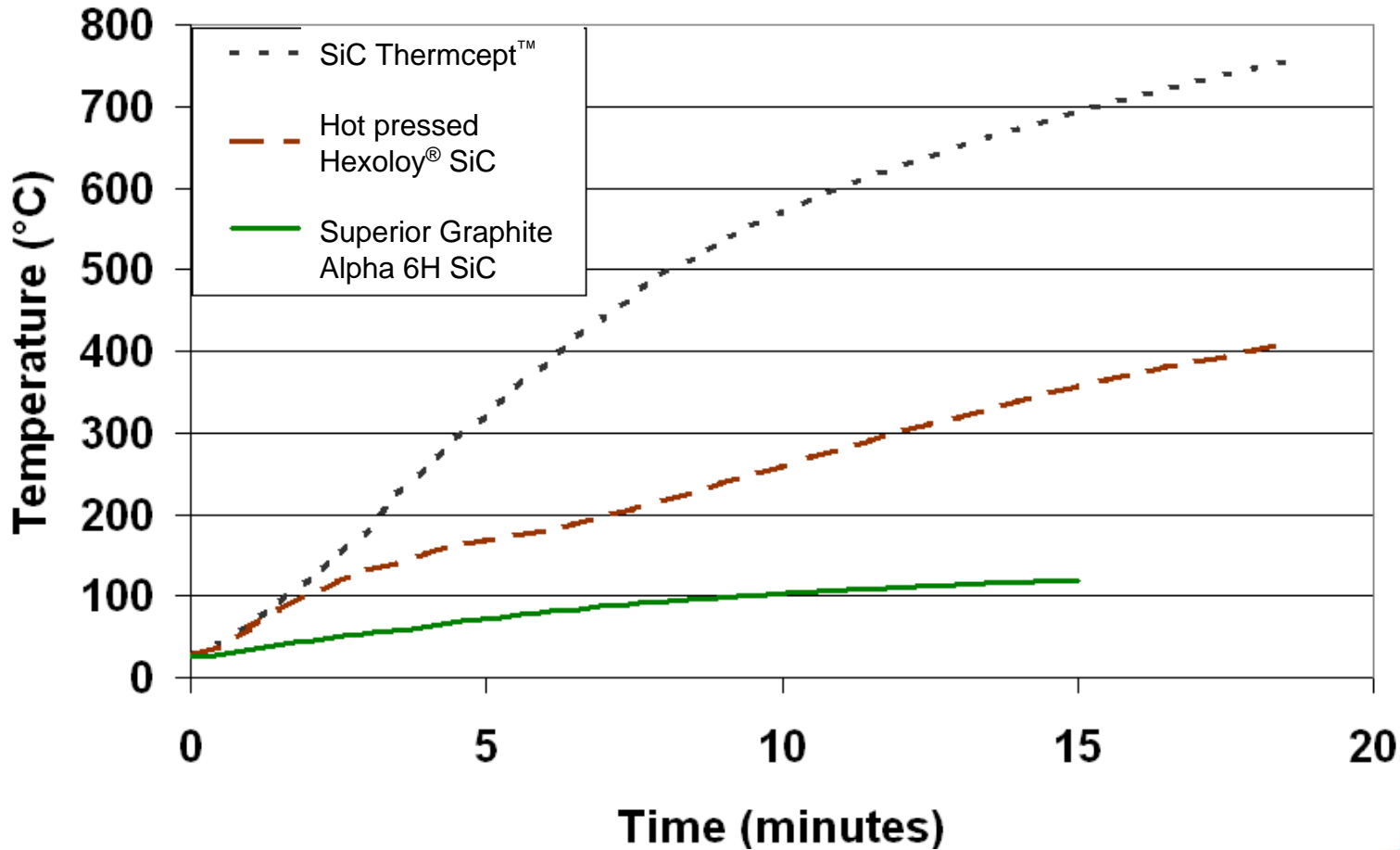
- To understand interactions
  - Systems- additives and polytypes
- Insulation for heat and atmosphere
  - MW transparent, high temperature
- Innovation!

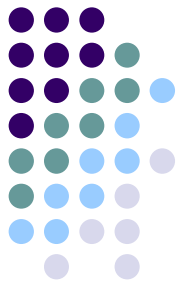




# Background

## Microwave Self Heating of SiC





# Microwaves - Dielectric Heating

$$\text{Tan } \delta = \varepsilon''/\varepsilon'$$

Conductivity increasing\* →



Transparent to microwaves  
Tan  $\delta < 0.01$

Absorb microwave (heats)  
Tan  $\delta \sim 0.01 - 2$

Reflects microwaves  
Tan  $\delta > 10$

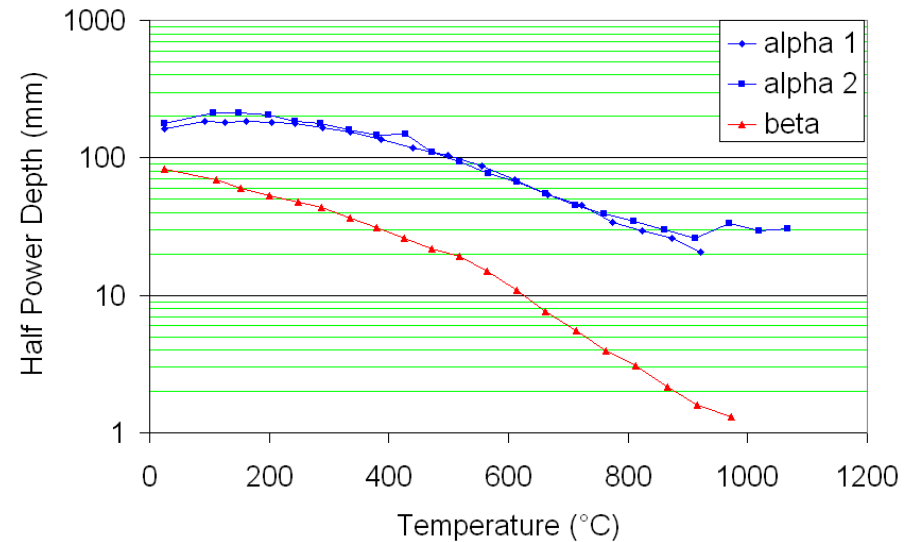
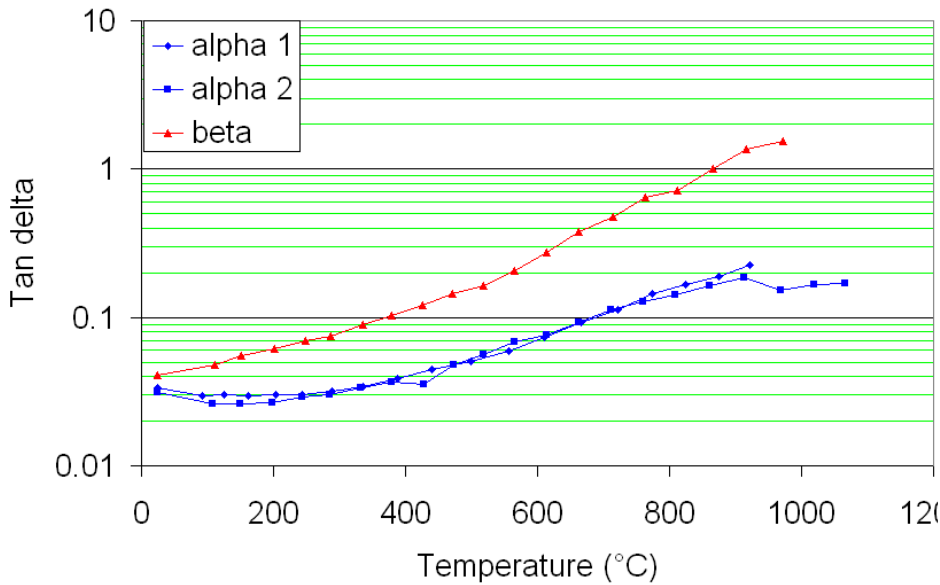
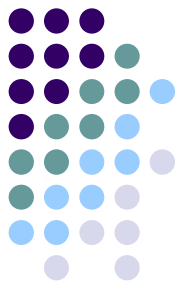
<b>20°C</b> <b>2.45 GHz</b>	<b>Alumina</b>	<b>Zirconia</b>	<b>Silicon Carbide</b>	<b>Aluminum (bulk**)</b>
<b>Tan <math>\delta</math></b>	<b>0.001</b>	<b>0.015</b>	<b>0.02-1.05</b>	<b><math>\infty</math></b>
<b>Penetration Depth (m)</b>	<b>12.8</b>	<b>1.0</b>	<b>0.004 - 0.05</b>	<b>0.000001</b>

\* Magnetic field may also induce currents leading to heating

\*\* Powder metals have measureable dielectric properties

# SiC Dielectric Data

## Alpha and Beta Phases



# SiC Study Comparisons



- Alpha vs. Beta
  - Superior Graphite SiC powders
- 6H vs. 4H/6H polytypes
  - Different alpha phases from different positions in electrode process
  - Co-precipitated with 10%  $Y_2O_3-Al_2O_3$



# Experimental Set-up

**RT**: Heat 15 min at 500 W

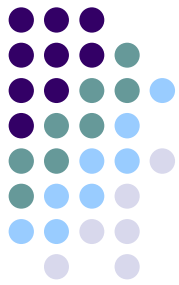
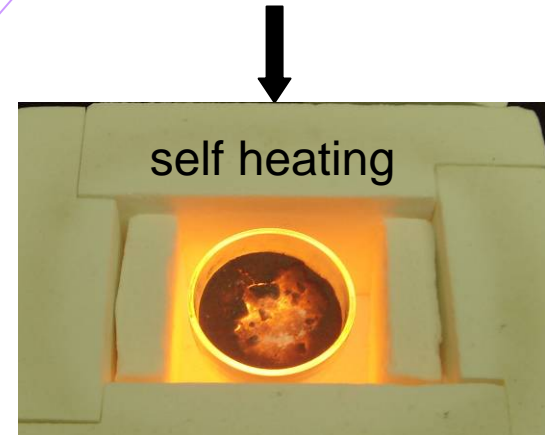
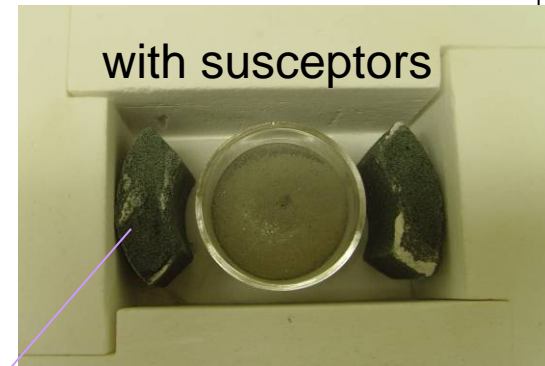
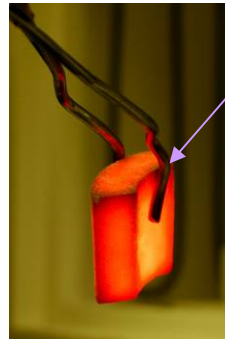
**600**: Heat to 600 °C w/ susceptors

Hold for 10 min

Remove susceptors

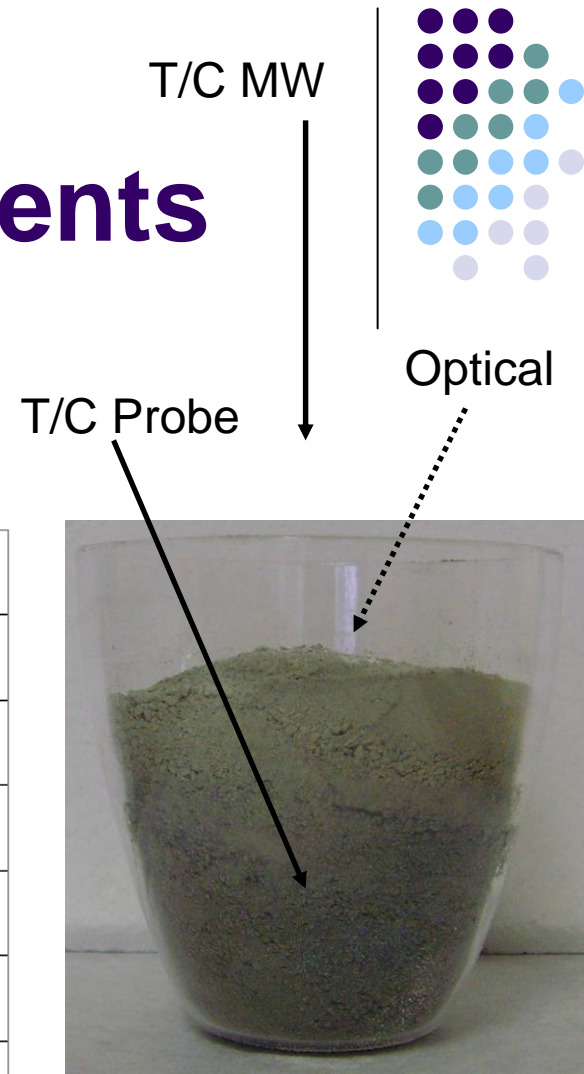
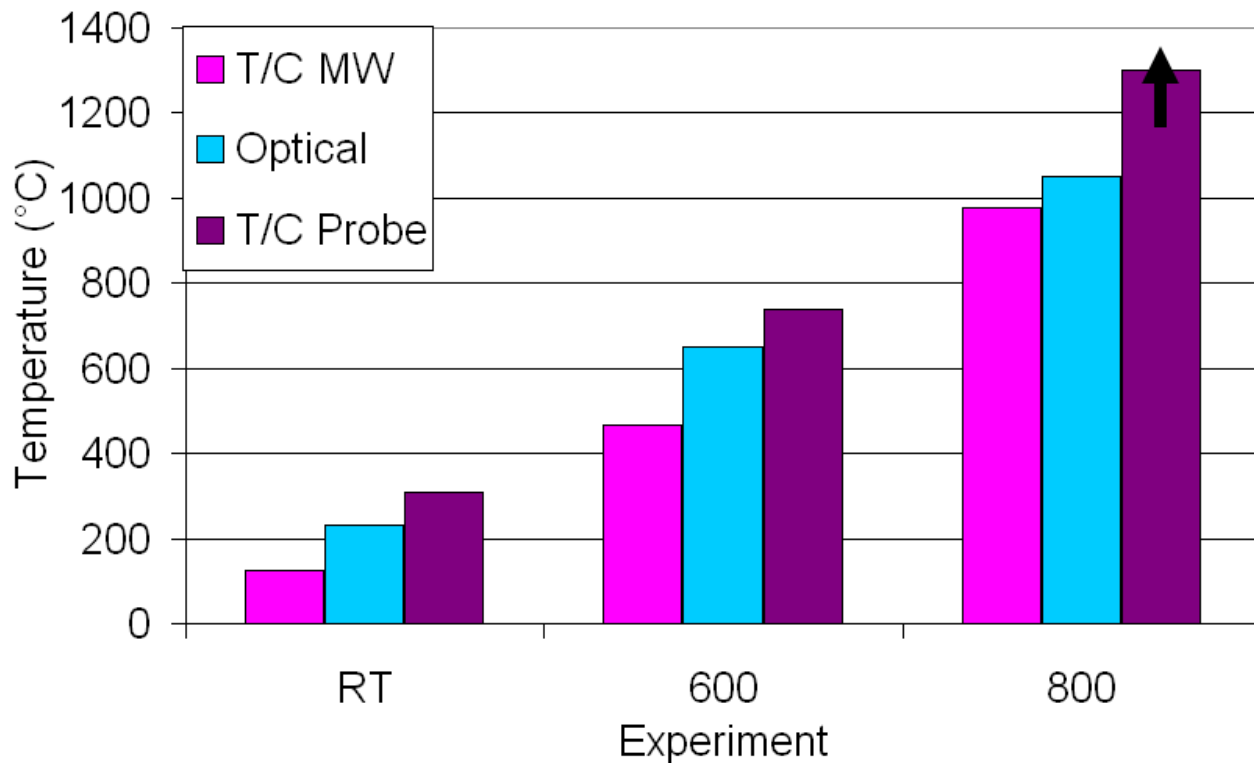
MW at 1000 W

**800**: same as 600 but to 800 °C



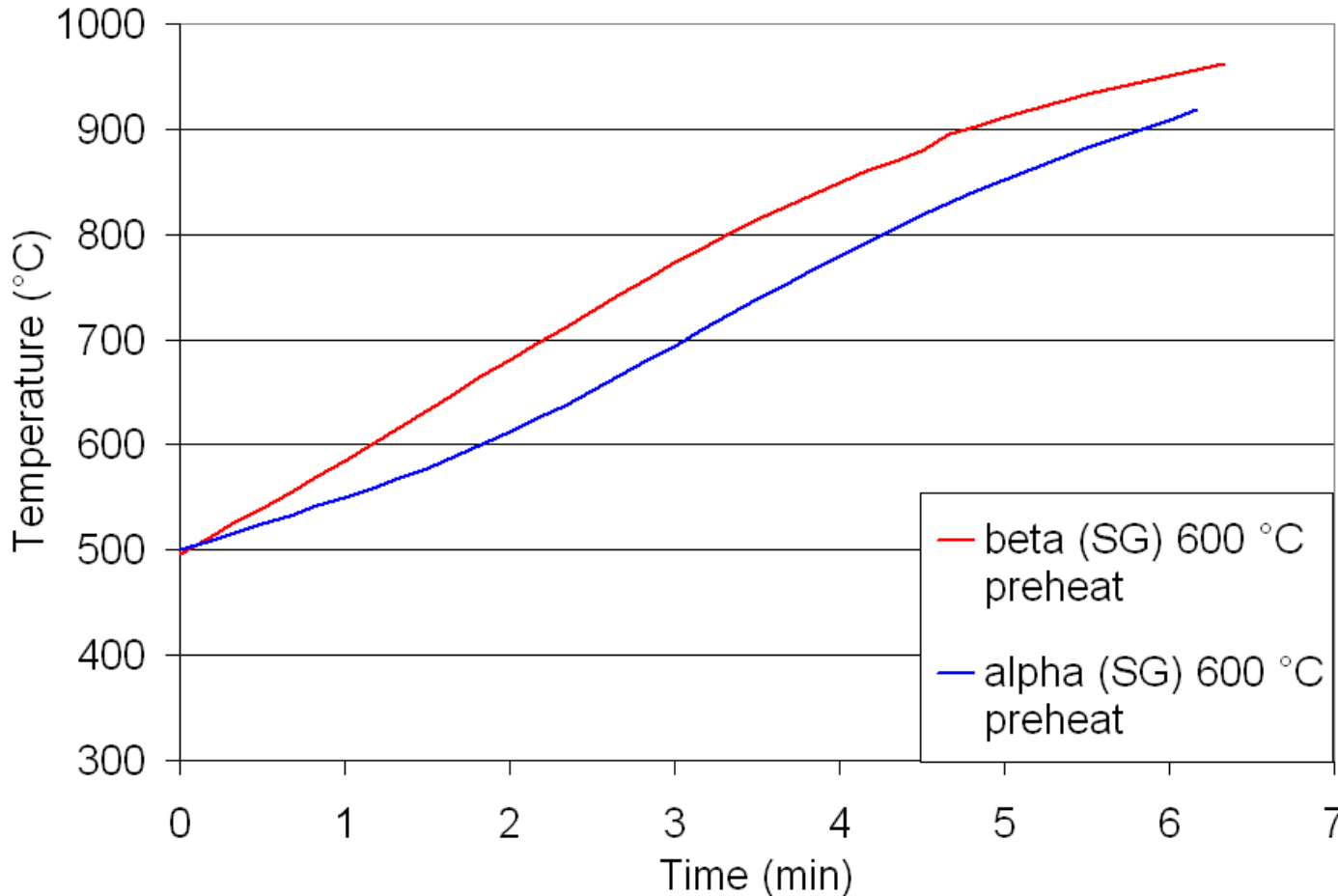
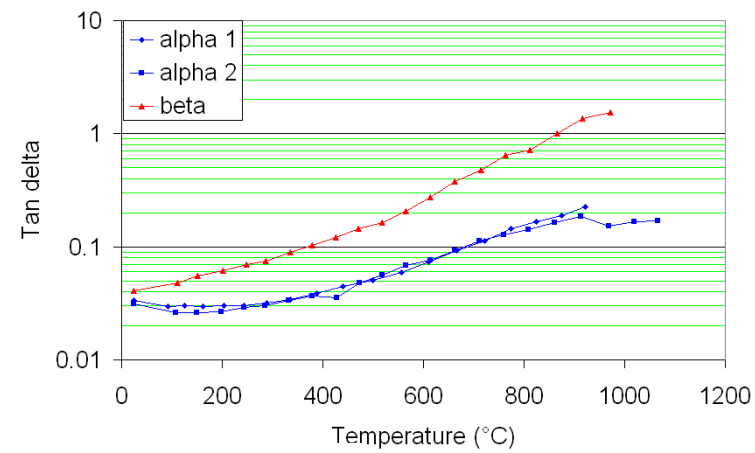
# Temperature Measurements

Maximum Temperature Achieved with alpha 6H SiC



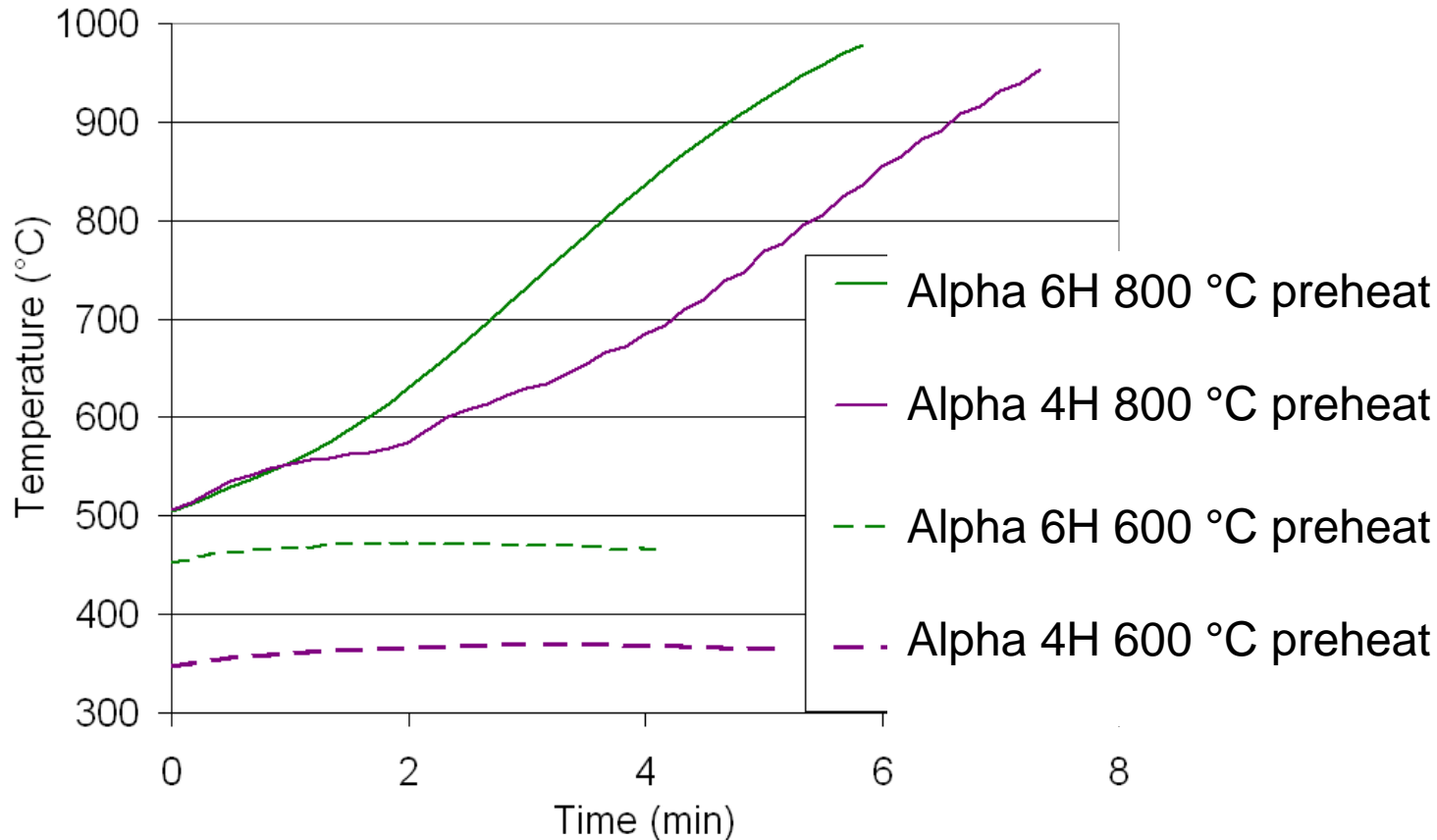
# SiC Self Heating

Alpha vs. Beta  
susceptor pre-heat



# SiC Self Heating

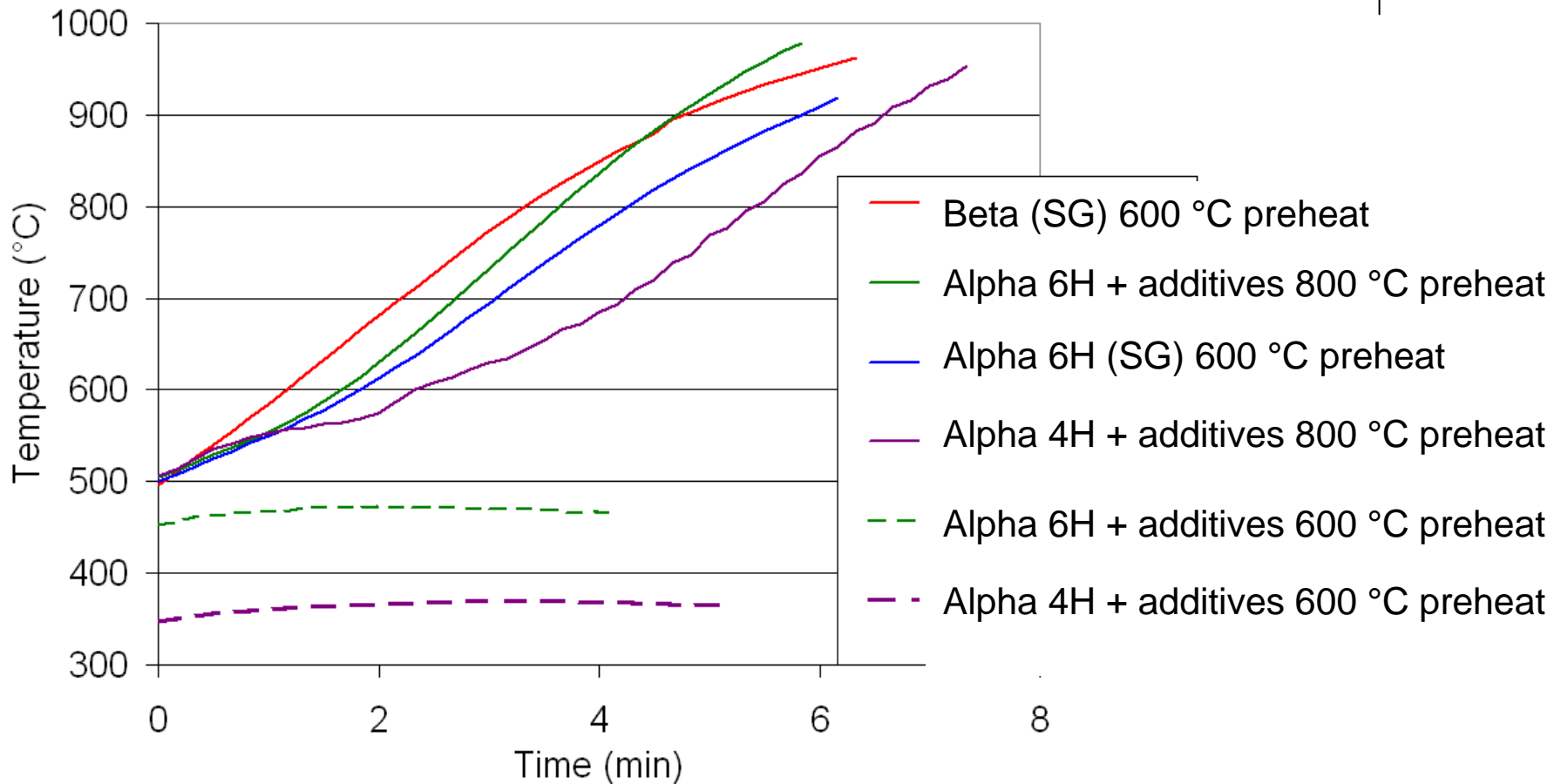
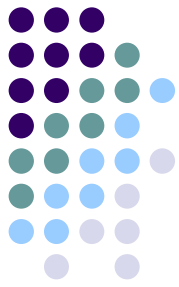
## 6H vs. 4H w/ susceptor pre-heat



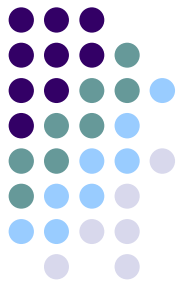
- Powders with co-precipitated additives
- 6H heated better compared to 4H mix

# SiC Self Heating Overview

after susceptor pre-heat

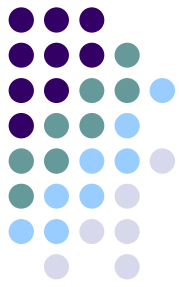


# Conclusions and Future Work



- Phase, polytype and additives effect heating
- Need more extensive dielectric testing
- Self heating studies to 1700 °C atmosphere control MAT™ kiln
  - Effect of phases and additives
- Ultra High temperature thermal package design for >1800 °C
  - 2 stage sintering
  - Liquid phase sintering

# Acknowledgements



Dr. Ron Hutcheon  
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