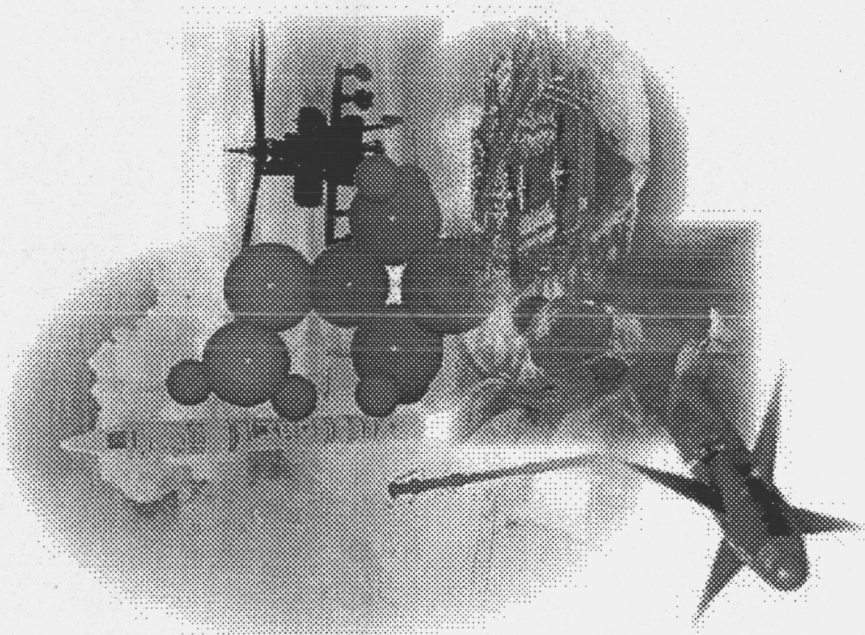




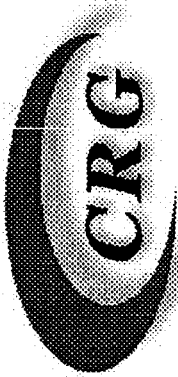
**Synlam™ Composite Mirror for  
Cryogenic Applications**

Jason Hermiller  
Cornerstone Research Group, Inc.  
Dayton OH 45440  
937.320.1877 &

Dr. H. Philip Stahl  
NASA Marshall Space Flight Center



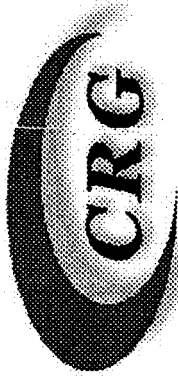
**18 August 2004**



*Cornerstone Research Group, Inc.*

## **ACKNOWLEDGMENT**

This presentation summarizes results of Small Business Innovation Research (SBIR) Phase I contract NNM05AA39C (1/21/05 - 7/25/05) funded by NASA Marshall Space Flight Center and managed by Dr. H. Philip Stahl.



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# OVERVIEW

- Program Introduction
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- Phase I Results
- Summary



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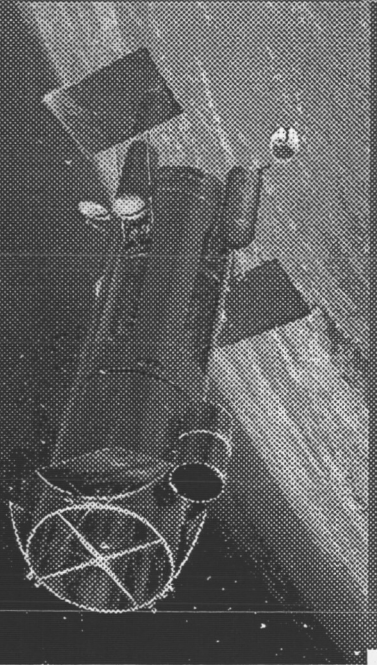


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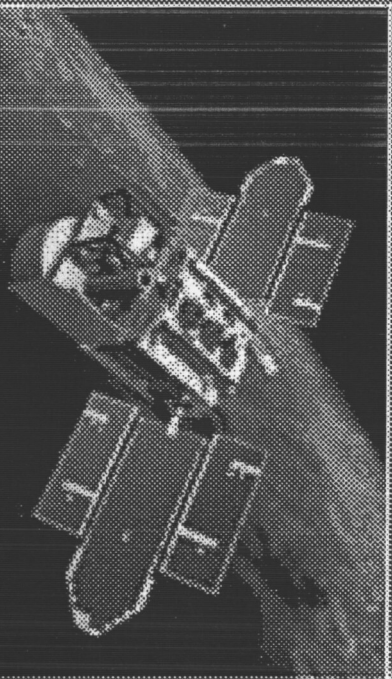
# PROGRAM INTRODUCTION

- **Applications: Space-Based Optics**

**Directed Energy  
(Laser) Systems**



**Imaging Systems**



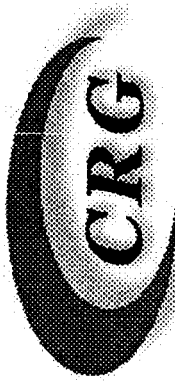
- **Operational Need:**
  - **Lighter**
  - **Tougher**
  - **Cheaper**

Images

L: [www.fas.org/spp/starwars/program/sbl.htm](http://www.fas.org/spp/starwars/program/sbl.htm)

R: [www.ball.com/aerospace/products bus.html](http://www.ball.com/aerospace/products bus.html)

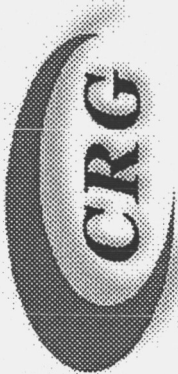
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# **PROGRAM INTRODUCTION: Material Design Elements**

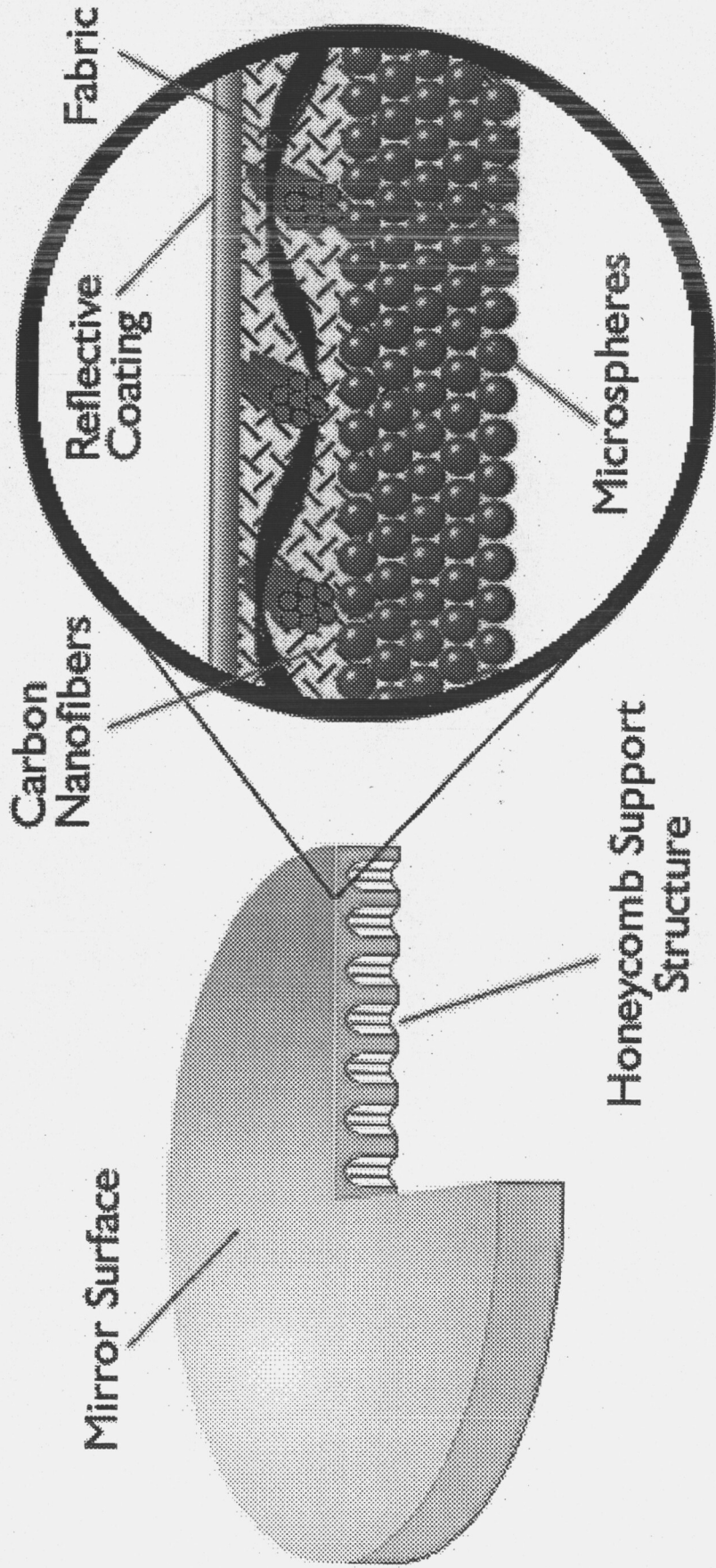
- **Space compatible:**
  - Radiation hard (to space ambient)
  - AO resistant  
(inherent or through practical coating)
  - Resistant to out-gassing in vacuum
- **Improvement over glass or metal mirrors:**
  - Lower areal density
  - Higher tolerance to thermal excursion (low CTE)
  - Improved strength (toughness & stiffness)
- **Compatible with obtaining optical surface**

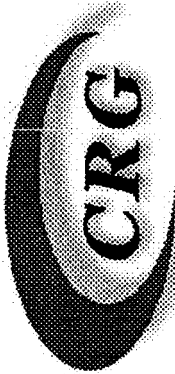


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# PROGRAM INTRODUCTION: Material Concept

## Multi-Component Composites

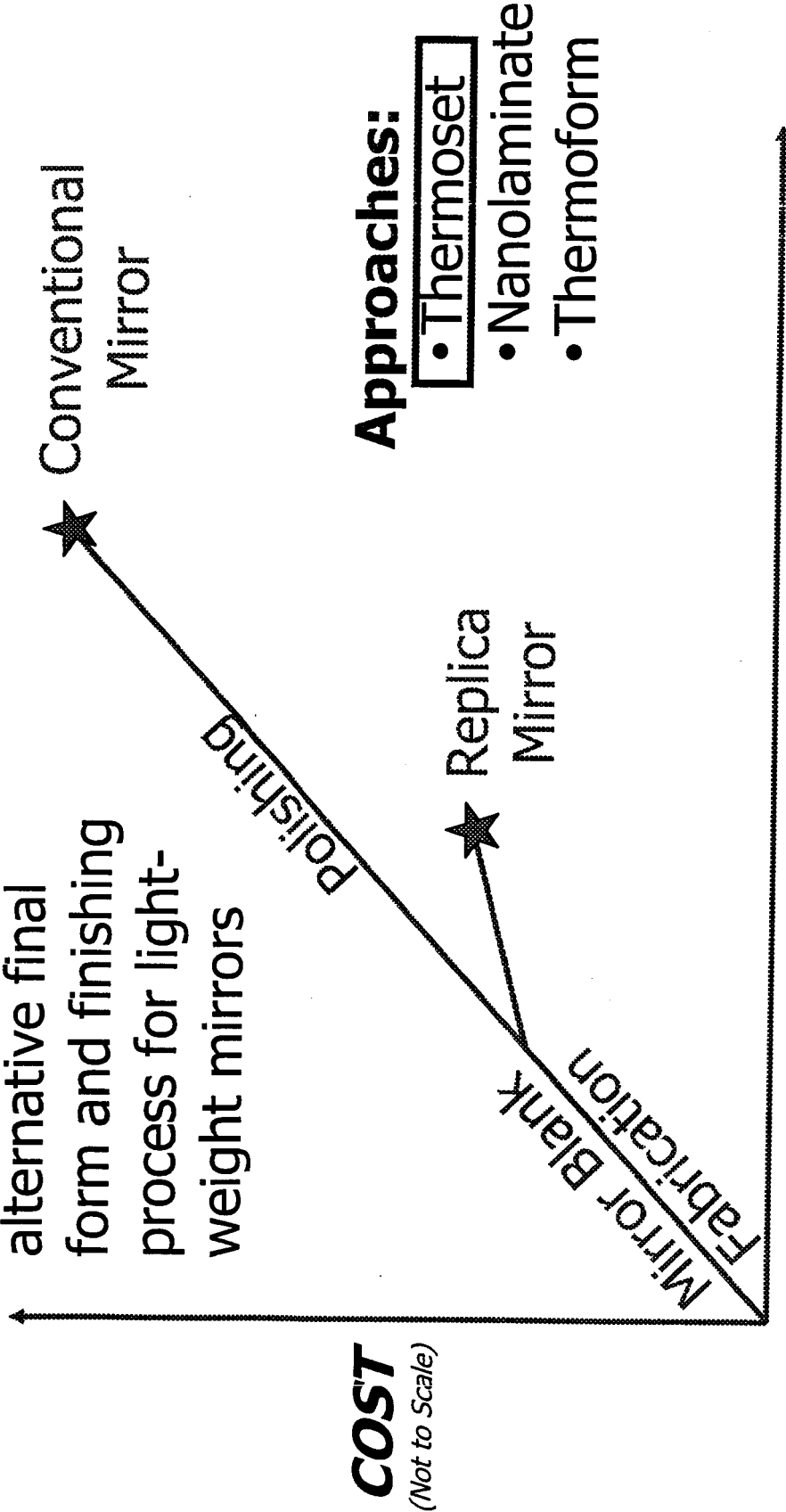




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# PROGRAM INTRODUCTION: Replication Technology

**Goal:** Develop alternative final form and finishing process for lightweight mirrors



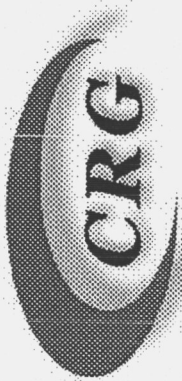
**COST**  
(Not to Scale)

**TIME**  
(Not to Scale)

## Approaches:

- Thermoset
- Nanolaminate
- Thermoform

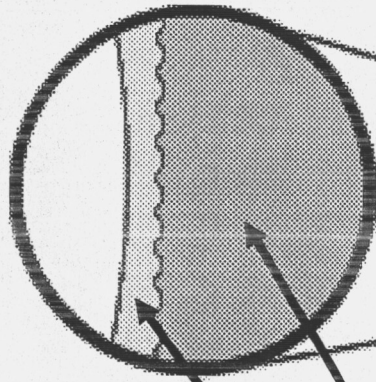




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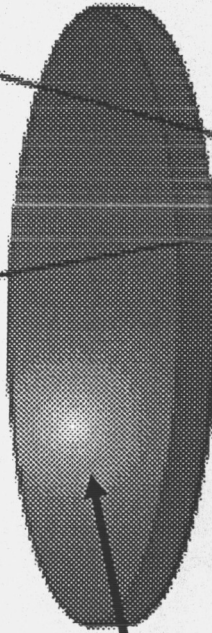
# PROGRAM INTRODUCTION: Thermoset Replica Concept

## Cast Optical Surface (no grinding or polishing)



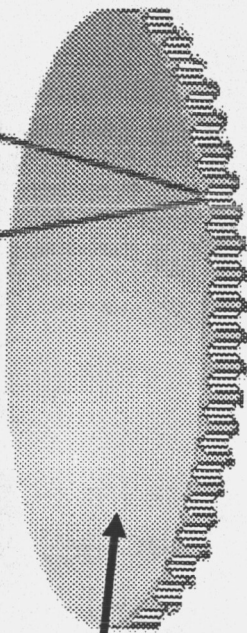
Polymer Mirror Surface

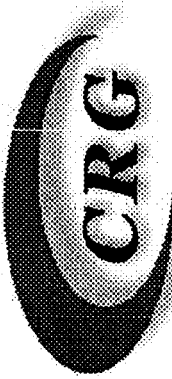
Mirror Substrate



Optical Quality Reusable Mold

Released Composite Mirror  
(final figure & finish)

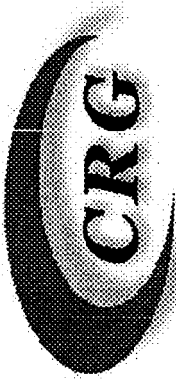




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# OVERVIEW

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## **PHASE I OBJECTIVES**

- 1. Improve SynLam™ performance at cryogenic temperatures**
- 2. Select cryogenic compatible adhesive**
- 3. Characterize candidate materials**
- 4. Assess candidates' feasibility for cryogenic mirrors**
- 5. Assess candidates' potential for mirror producibility**



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# OVERVIEW

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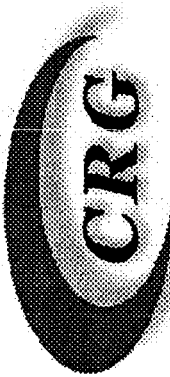


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# PHASE I RESULTS: Fillers

- **Primary material properties**
  - **CTE**
  - **Modulus**
  - **Density**
- **Cost and Availability**

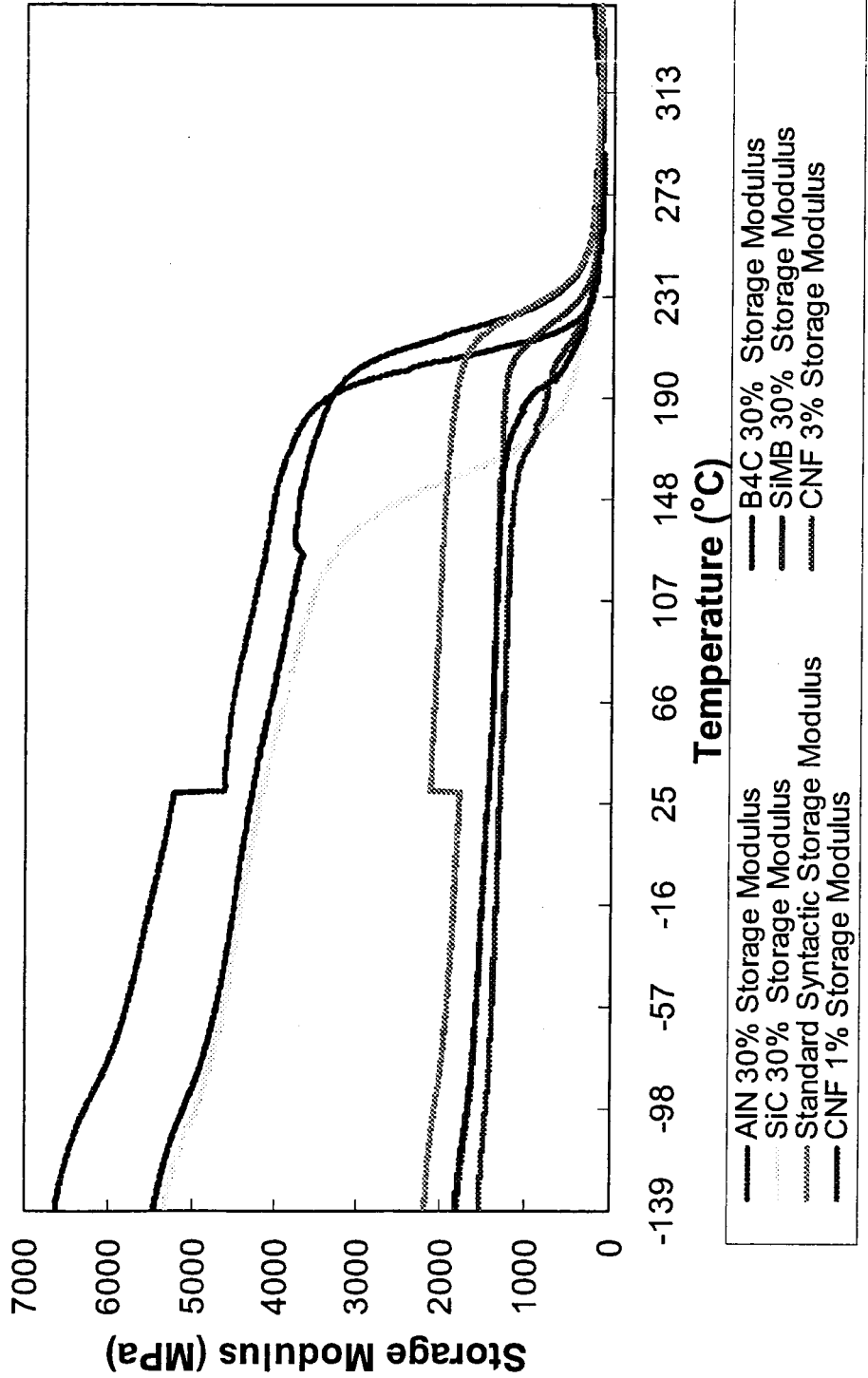
	Filler Type				
	Aluminum Nitride (AlN)	Boron Carbide (B4C)	Silicon Carbide (SiC)	Glass Microballoons (SIMB)	Carbon Nanofibers (CNF)
Loading	30% volume	30% volume	30% volume	30% volume	3% volume
	20% volume	20% volume	20% volume	20% volume	1% volume
	10% volume	10% volume	10% volume	10% volume	

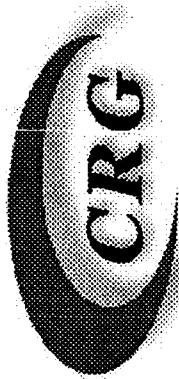


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# PHASE I RESULTS: Syntactic Modulus Increase

### Comparison of Fillers Full Range

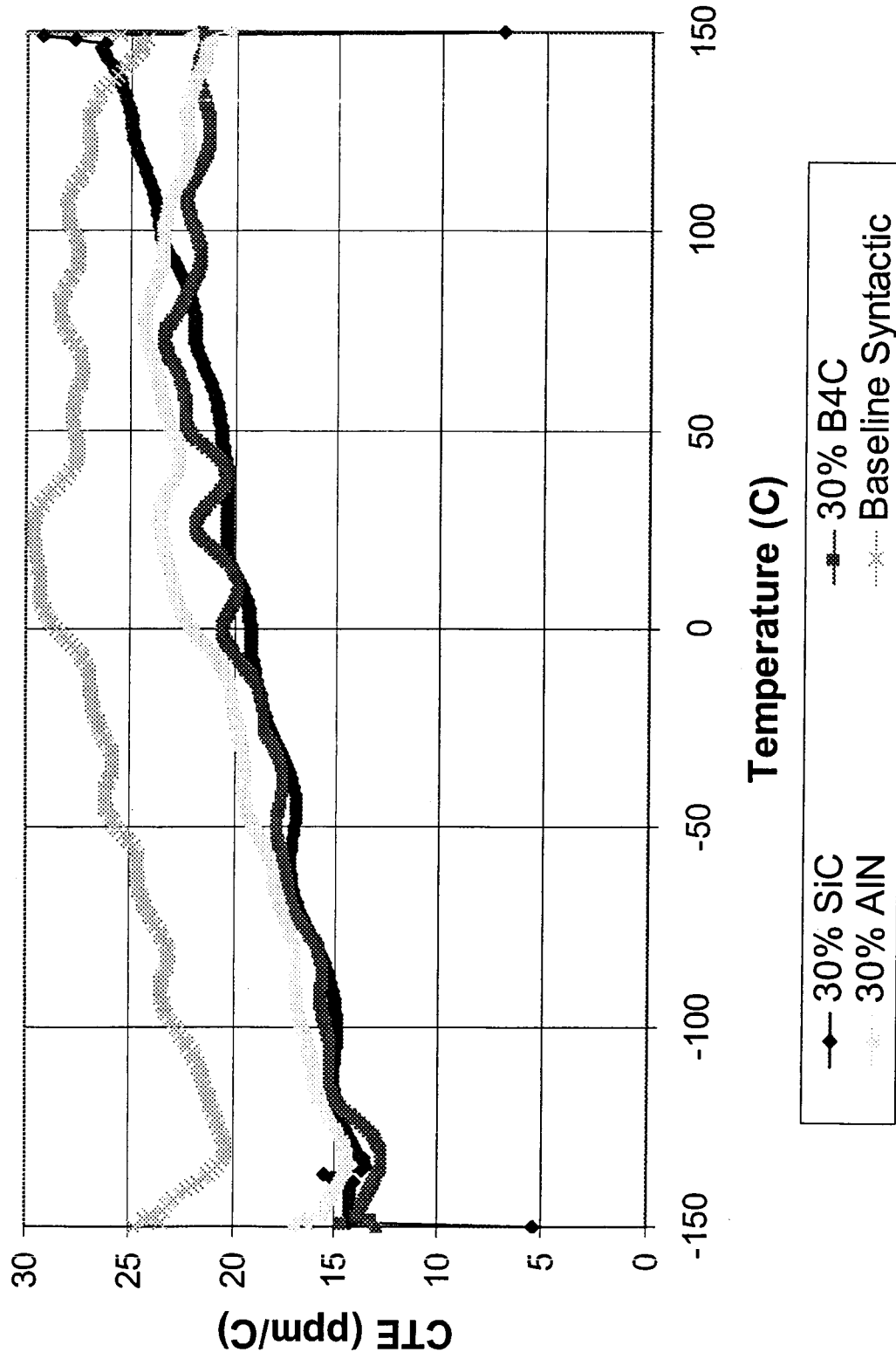




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# PHASE I RESULTS: Syntactic CTE Reduction

## 30% by Volume of Fillers





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## **PHASE I RESULTS: Fillers**

- **CTE**
  - **AlN largest effect**
  - **SiC and B4C similar performance**
  - **CNF and additional microballoons- decreased performance**
- **Modulus**
  - **SiC and B4C similar performance**
  - **CNF and additional microballoons- no improvement**
- **Down Selected SiC and B4C**
  - **B4C chosen for lower density**

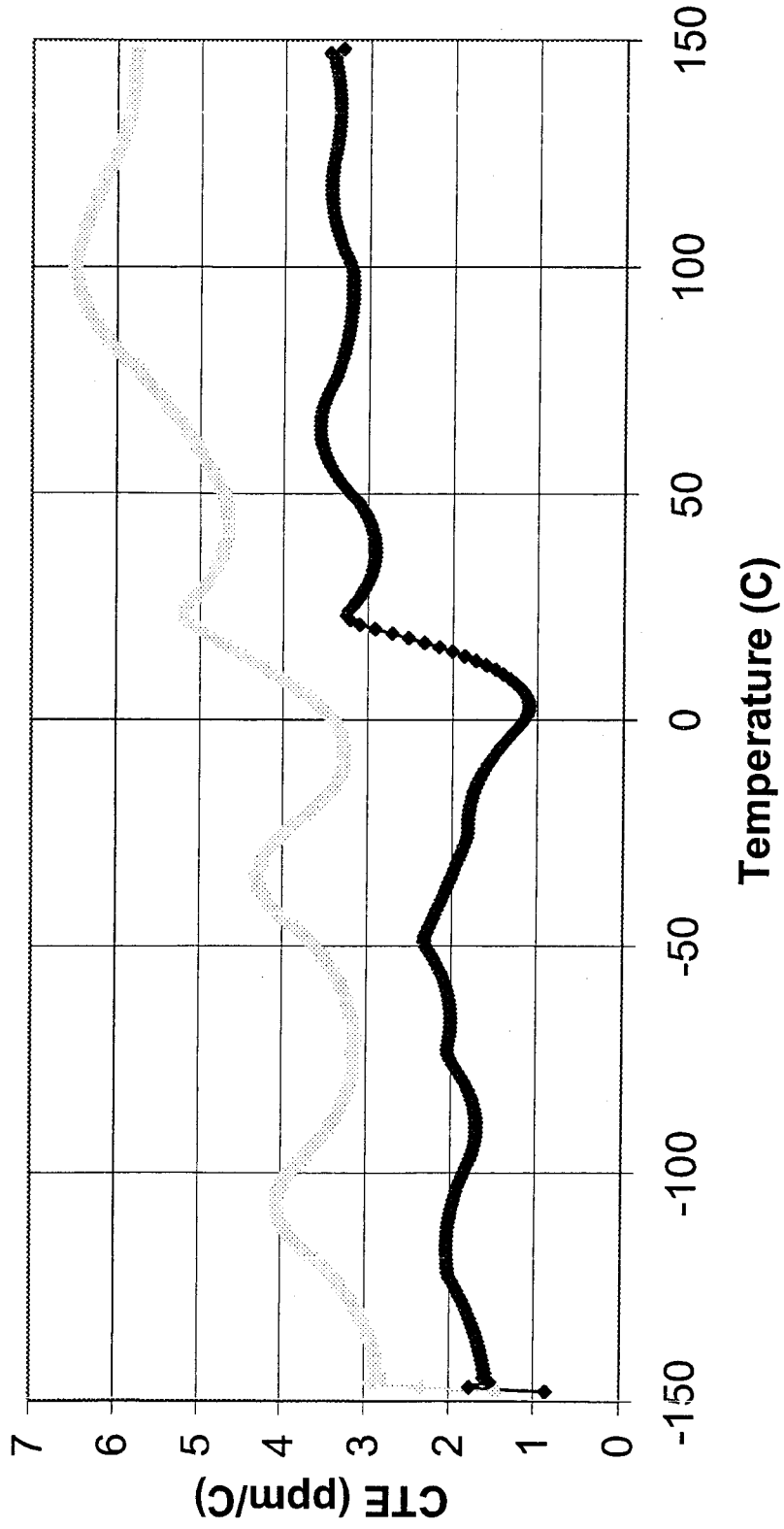




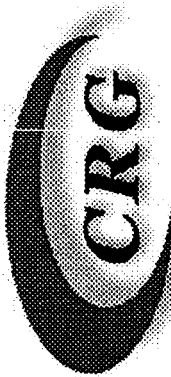
Corning Research Group, Inc.

# PHASE I RESULTS: CTE Reduction

## CTE of Boron Carbide Filled Synlam Compared with Baseline Synlam of the Same Thickness



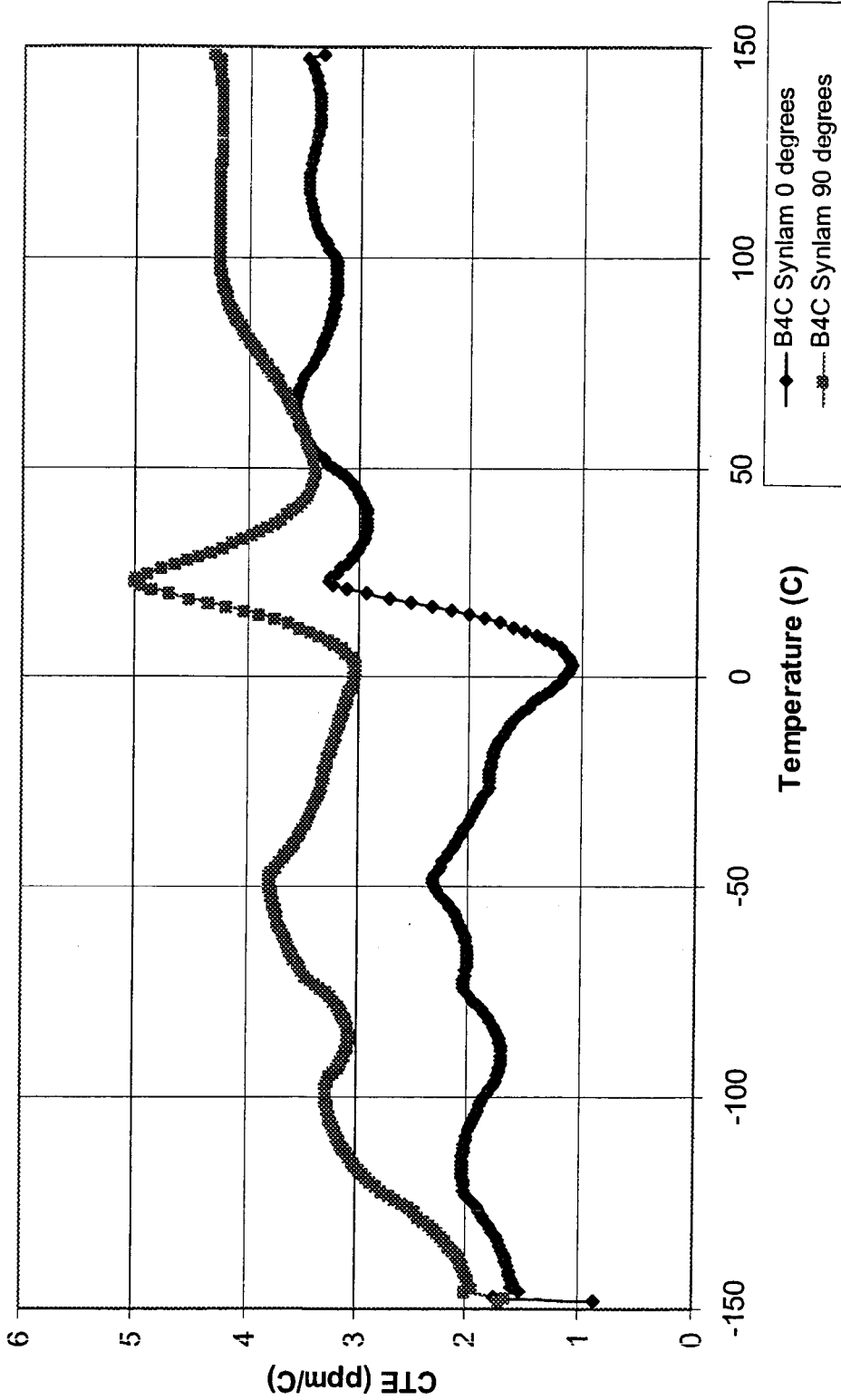
◆ B4C Synlam    ··· Baseline Synlam



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# PHASE I RESULTS: Fiber Orientation

CTE Comparison for Along Fibers and Between Fibers of a Synlam



Some Anisotropic Behavior in  
plane of composite

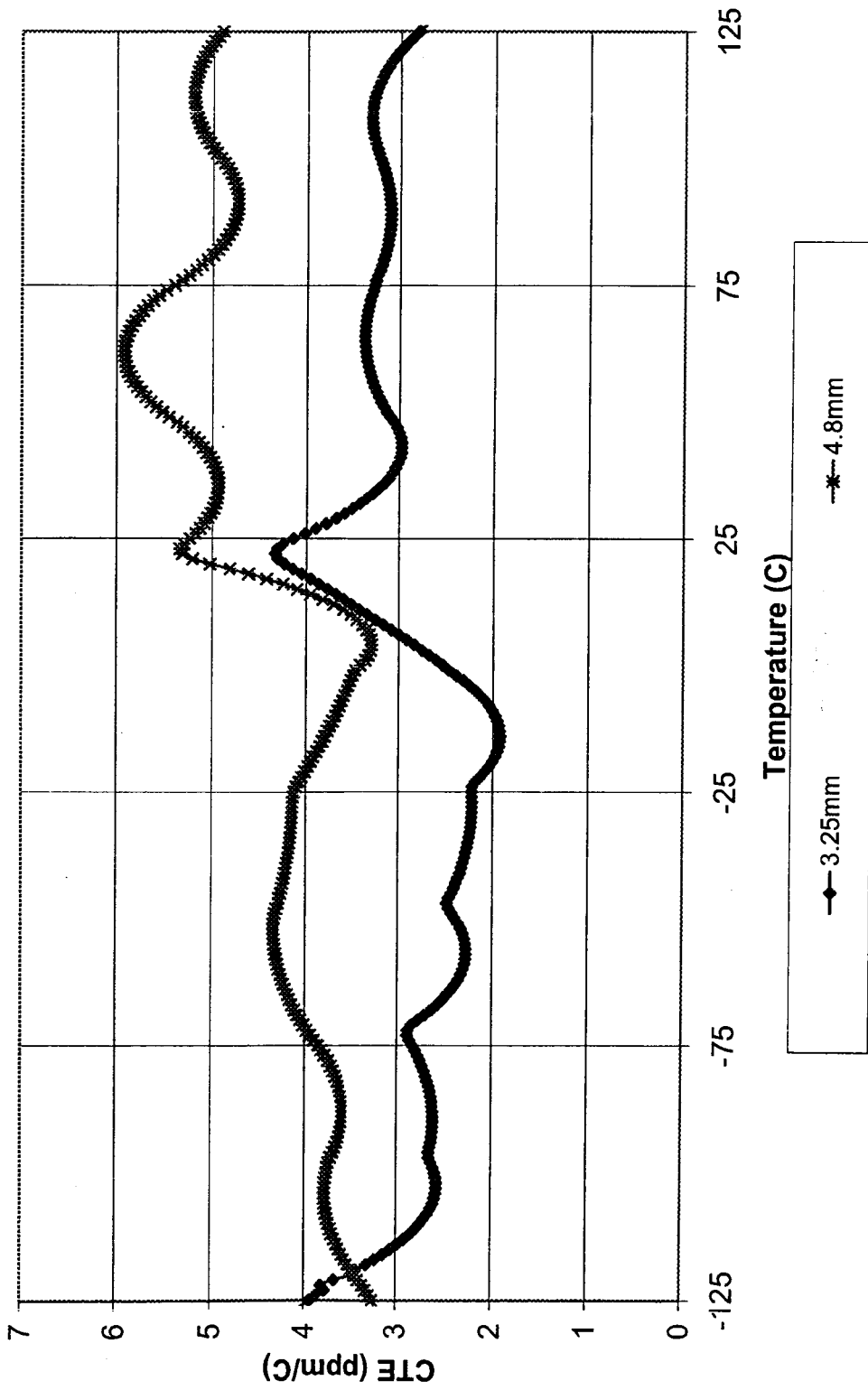
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# PHASE I RESULTS:

## CTE for Synlam™ at Varying Thickness



## CTE of SynLam™ varying composite thickness

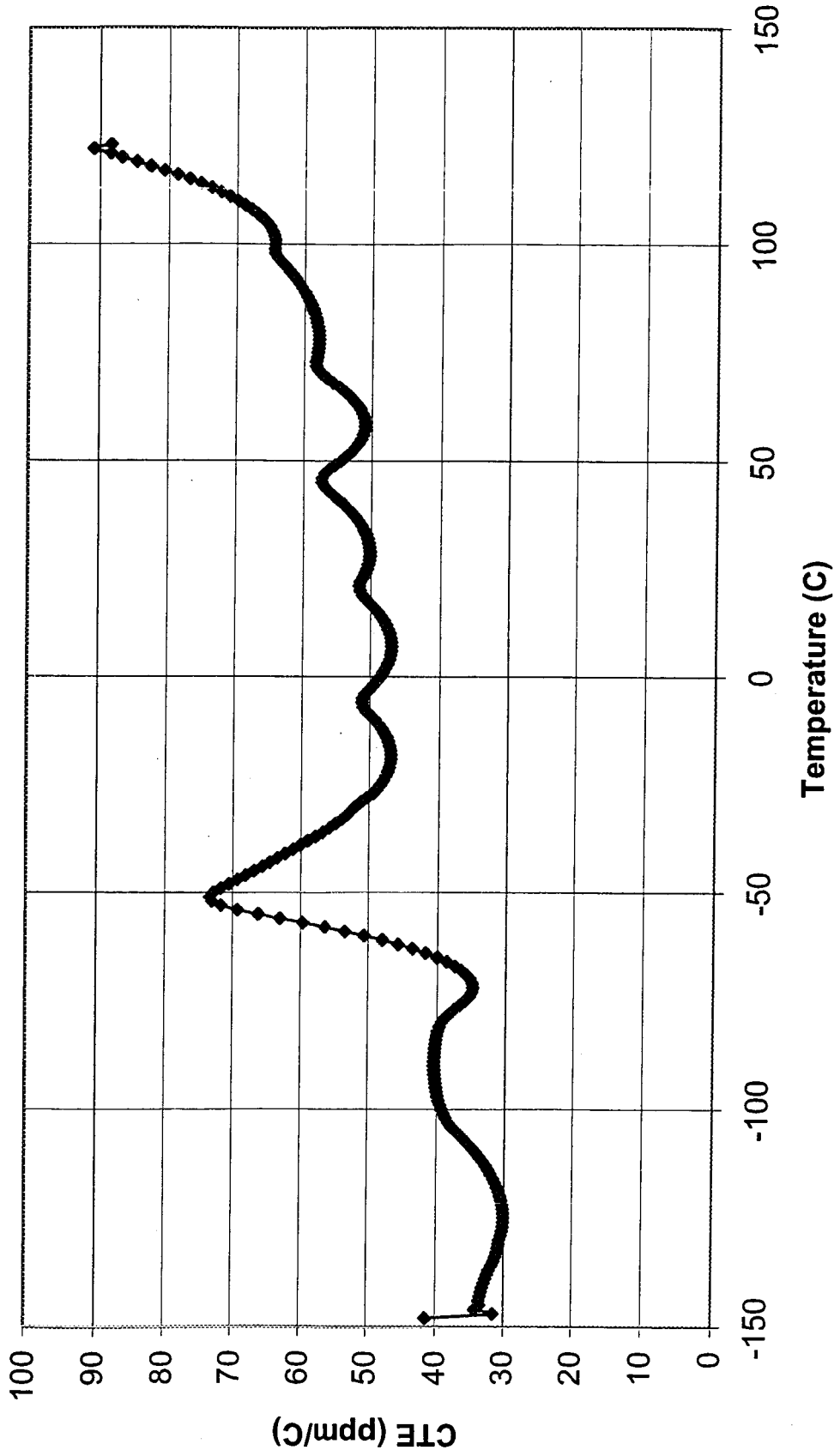
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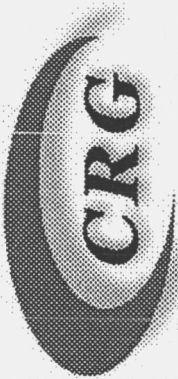
# PHASE II RESULTS: Adhesive

## Masterbond Supreme 10HT CTE



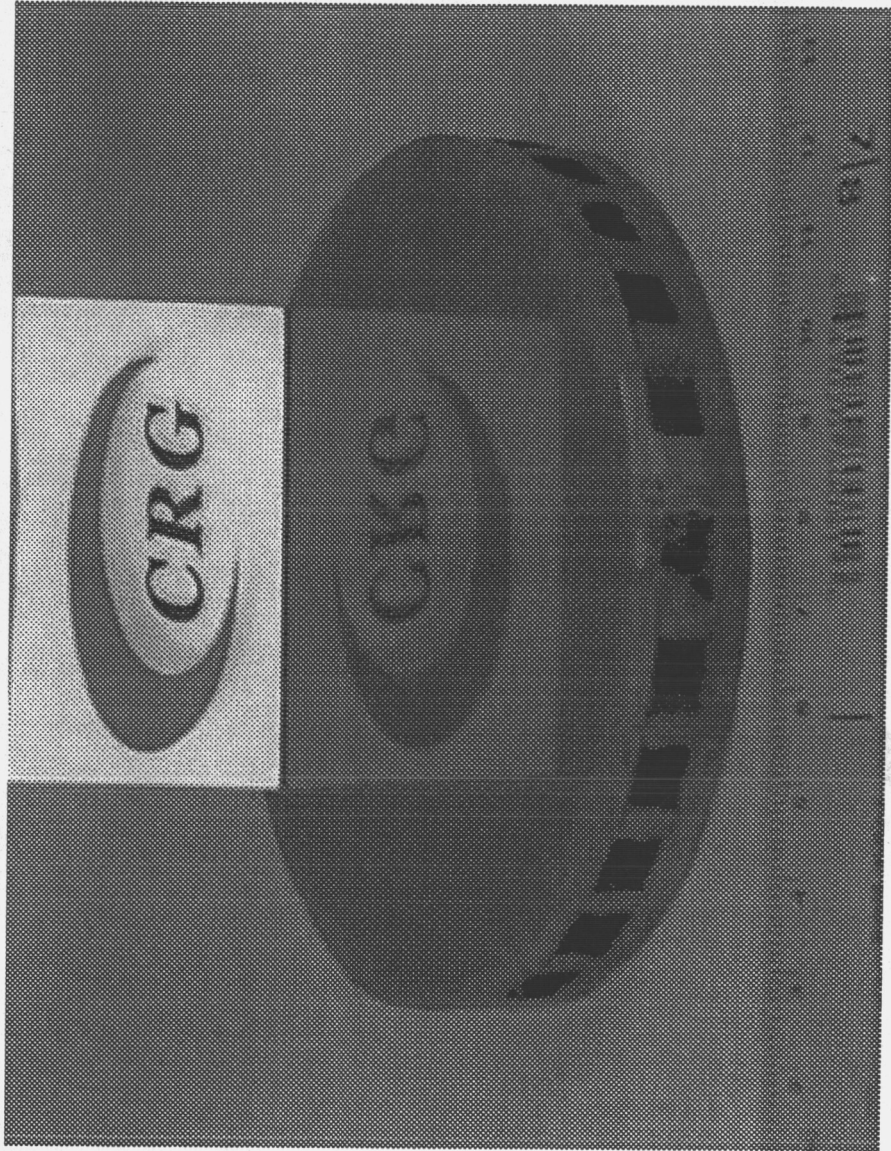
**High CTE of the adhesive adds  
to rib quilting**

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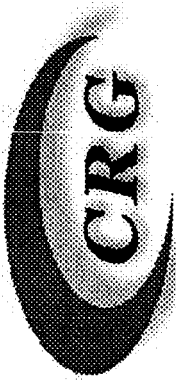
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# PHASE I RESULTS: Reflective Surface



**Prototype Mirror Finished:  
Cryogenic Interferometry Pending**

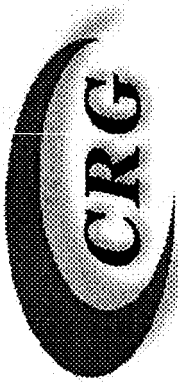
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## **PHASE I RESULTS: Issues For Phase II**

- **Materials**
  - Other fillers:  $ZrW_2O_8$ , -CTE glass
  - Lower CTE adhesive for cryogenic use
  
- **Optical Surface**
  - Improving optical surface
  - Interface between substrate and optical surface
  - Internal bonding of mirror structure (print-through issue)
  - Scale-up to prototype size

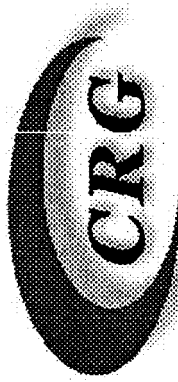


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## PHASE I SUMMARY

# *Composite Replica Mirrors for Cryogenic Lightweight Space Optics*

- Operational Benefits
  - Reduced mirror areal density
  - Tougher & stronger mirrors
  - Reduced fabrication time & cost
- Improvement On Baseline Synlam™
  - Demonstrated material densities from 0.43 to 1.1 g/cc
  - Demonstrated an increase in material stiffness
  - Demonstrated a reduction in Coefficient of Thermal Expansion and increase of thermal conductivity
- Cryogenic Adhesive Identified
- Demonstrated replication process on 10 cm flat composite mirror
- Fabrication time of prototype for this program was accomplished in less than 1 week. Processes scalable to meter scale apertures.