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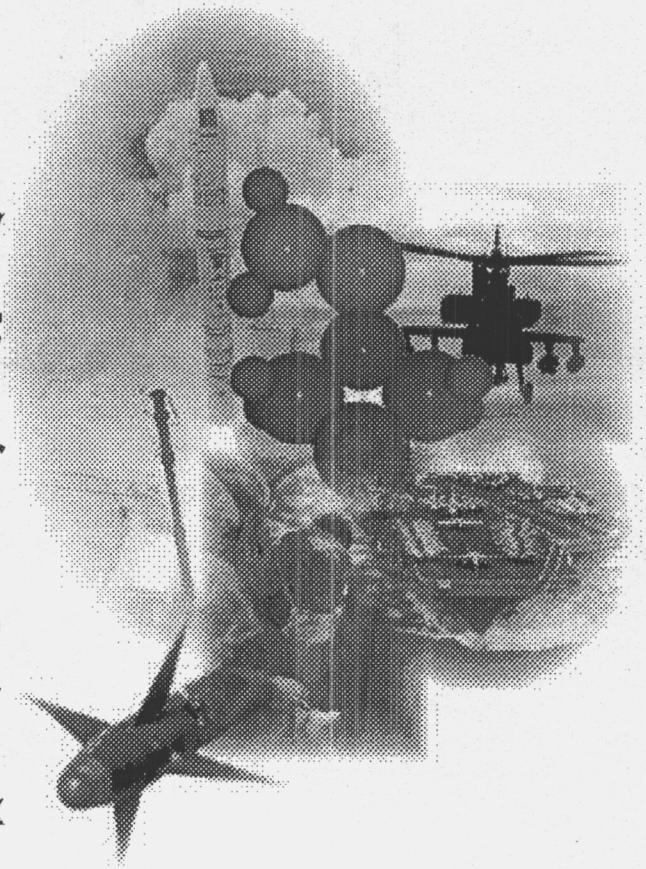
Synlam™ Composite Mirror for Cryogenic Applications



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Applying Tomorrow's Materials Today

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ACKNOWLEDGMENT

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OVERVIEW

- Program Introduction
- Phase I Objectives
- Phase I Results
- Summary

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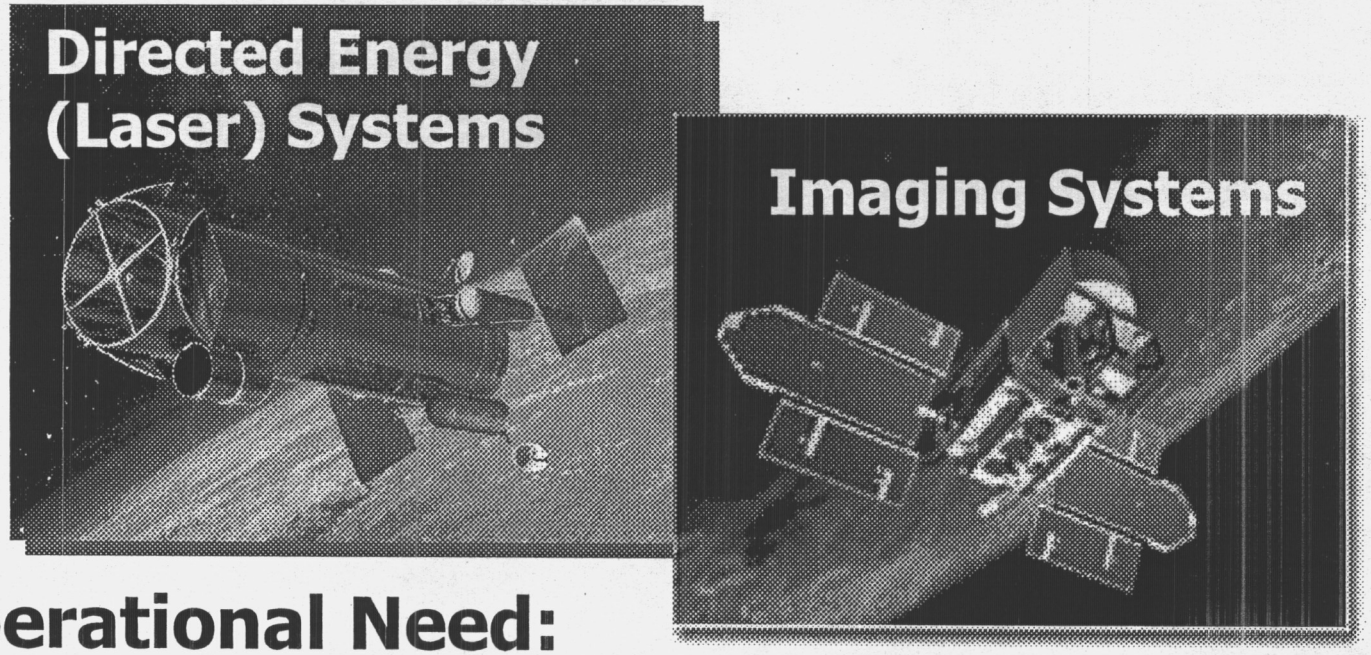
PROGRAM INTRODUCTION

- **Applications: Space-Based Optics**



- **Operational Need:**
  Improve on glass & metal mirrors
  - **Lighter**
  - **Tougher**
  - **Cheaper**

Images
L: www.fas.org/spp/starwars/program/sbl.htm
R: www.ball.com/aerospace/prod rs 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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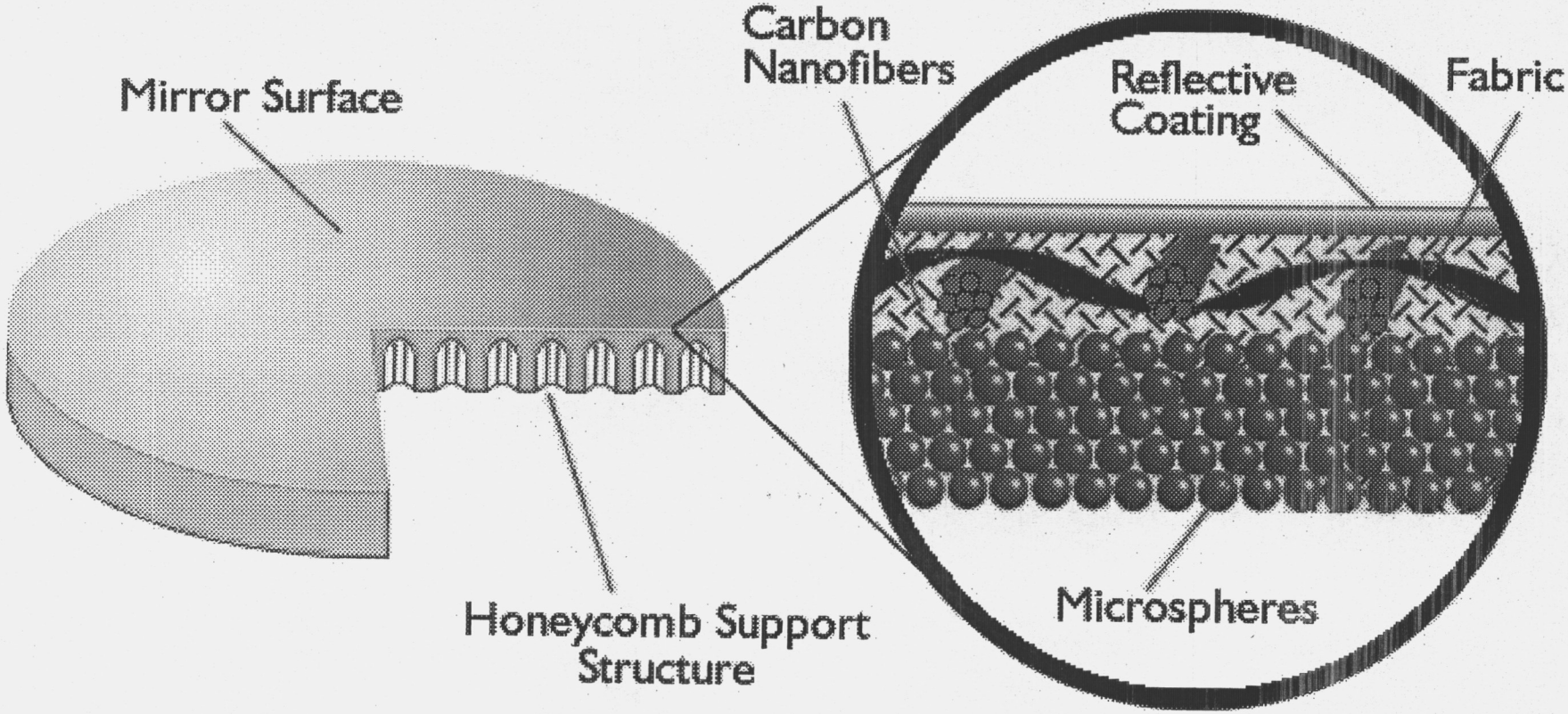
PROGRAM INTRODUCTION:
Material Concept

Multi-Component Composites



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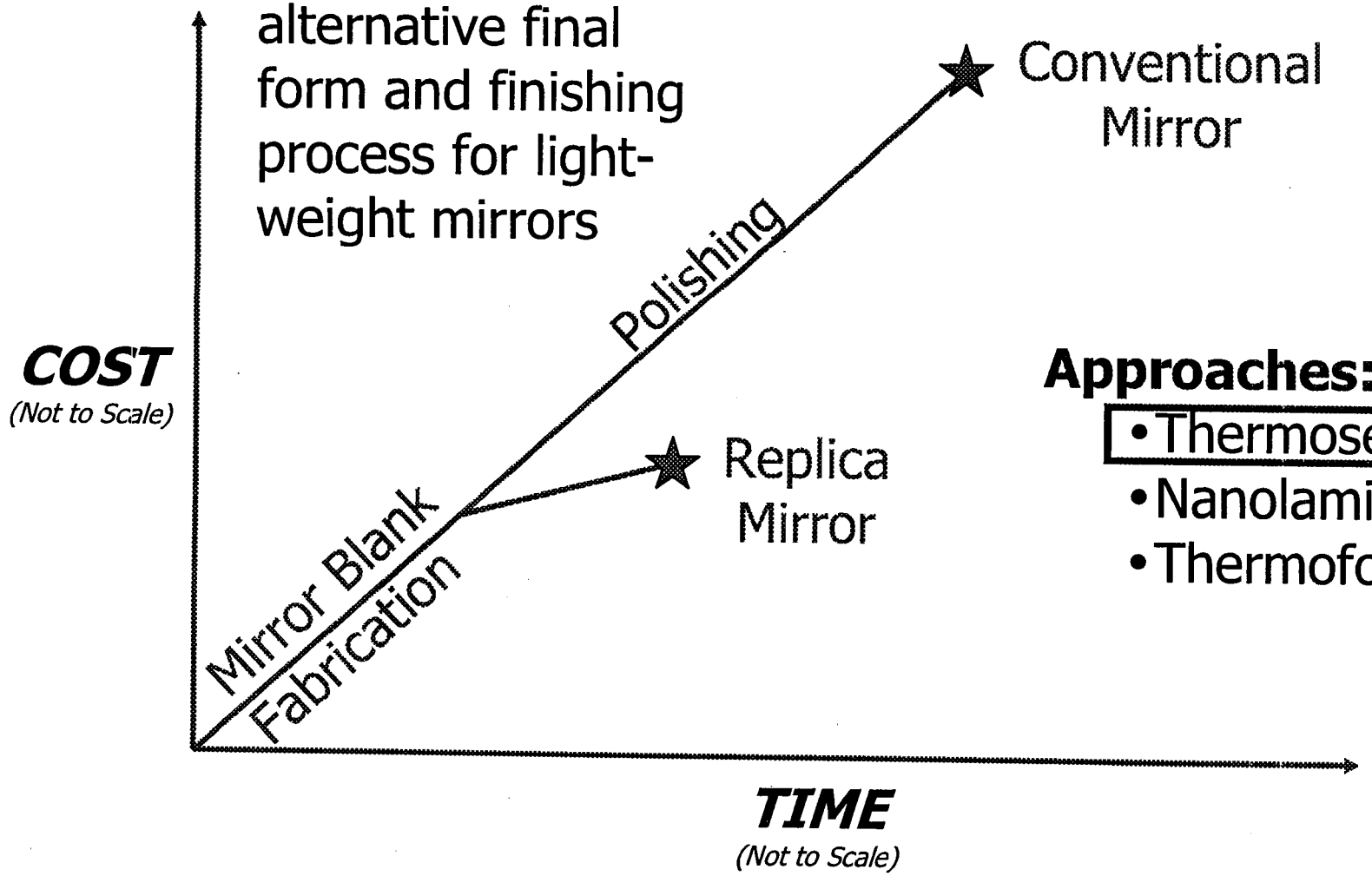
PROGRAM INTRODUCTION: Replication Technology

Goal: Develop alternative final form and finishing process for light-weight mirrors



Approaches:

- Thermoset
- Nanolaminate
- Thermoform

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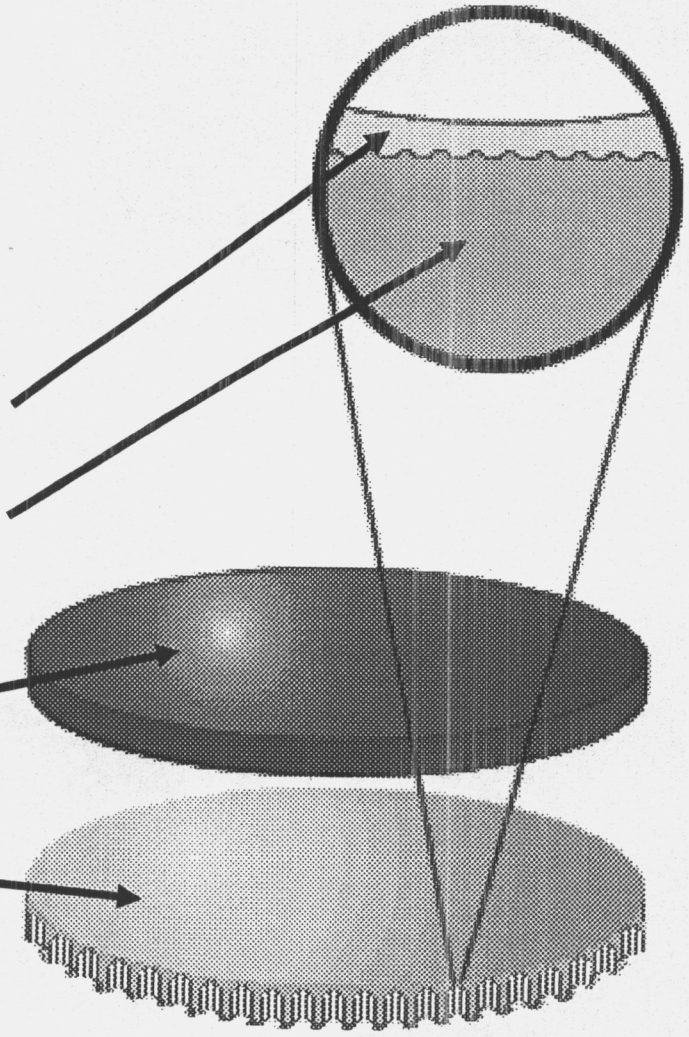
PROGRAM INTRODUCTION:
Thermoset Replica Concept

Cast Optical Surface
(no grinding or polishing)



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- **Phase I Objectives**
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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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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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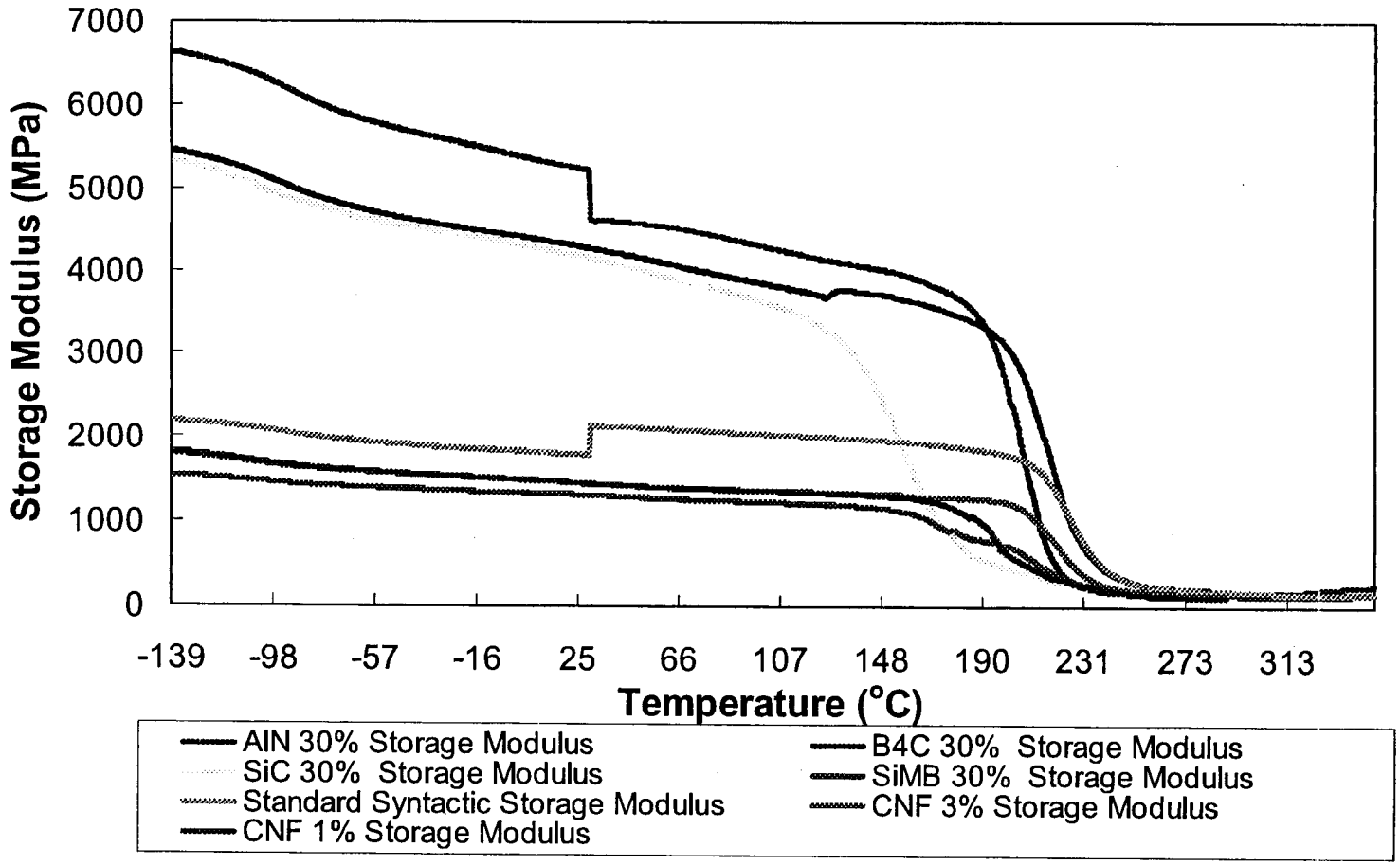
PHASE I RESULTS:
Syntactic Modulus Increasse

Comparison of Fillers
Full Range



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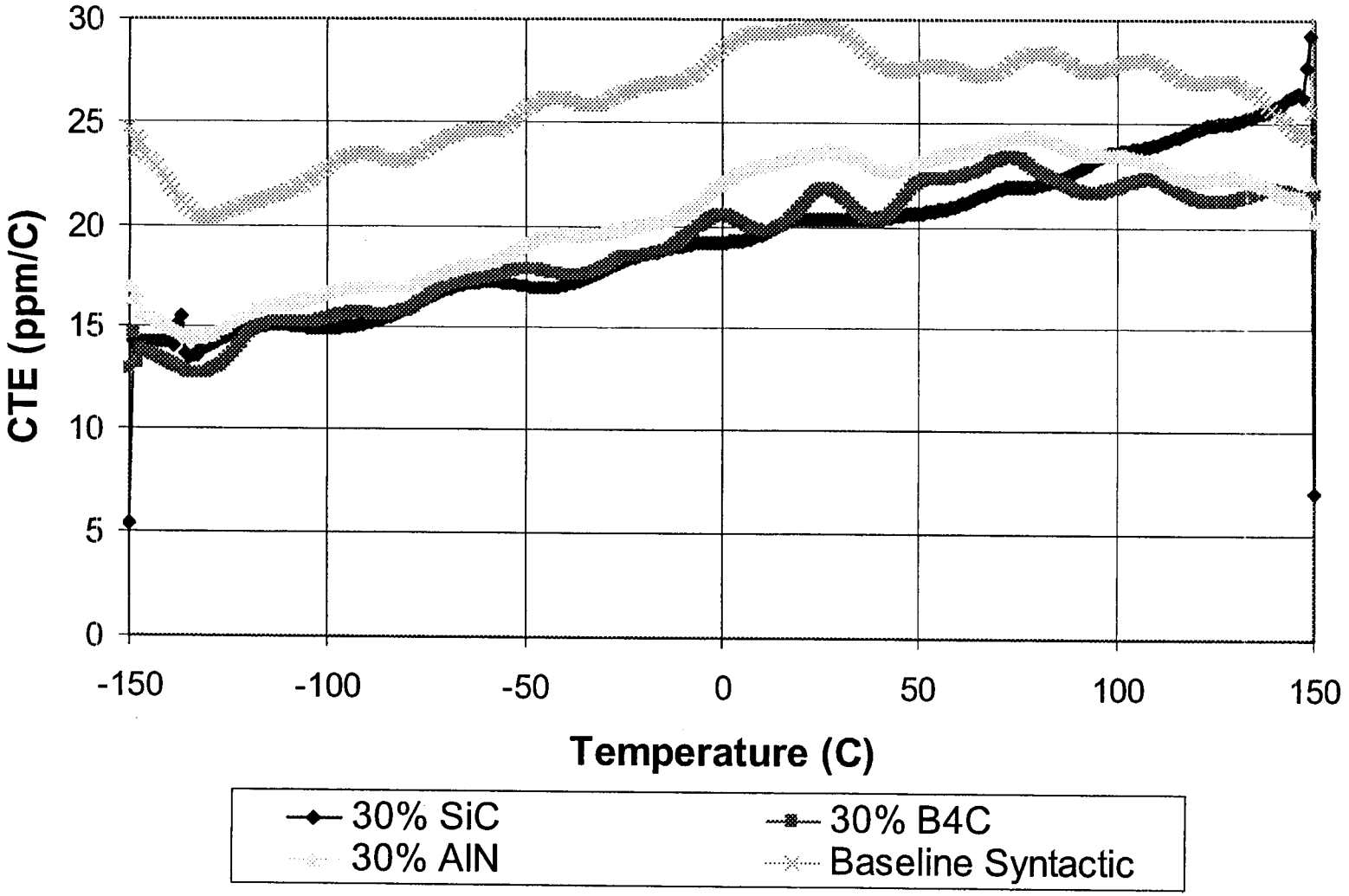
PHASE I RESULTS: Syntactic CTE Reduction

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**

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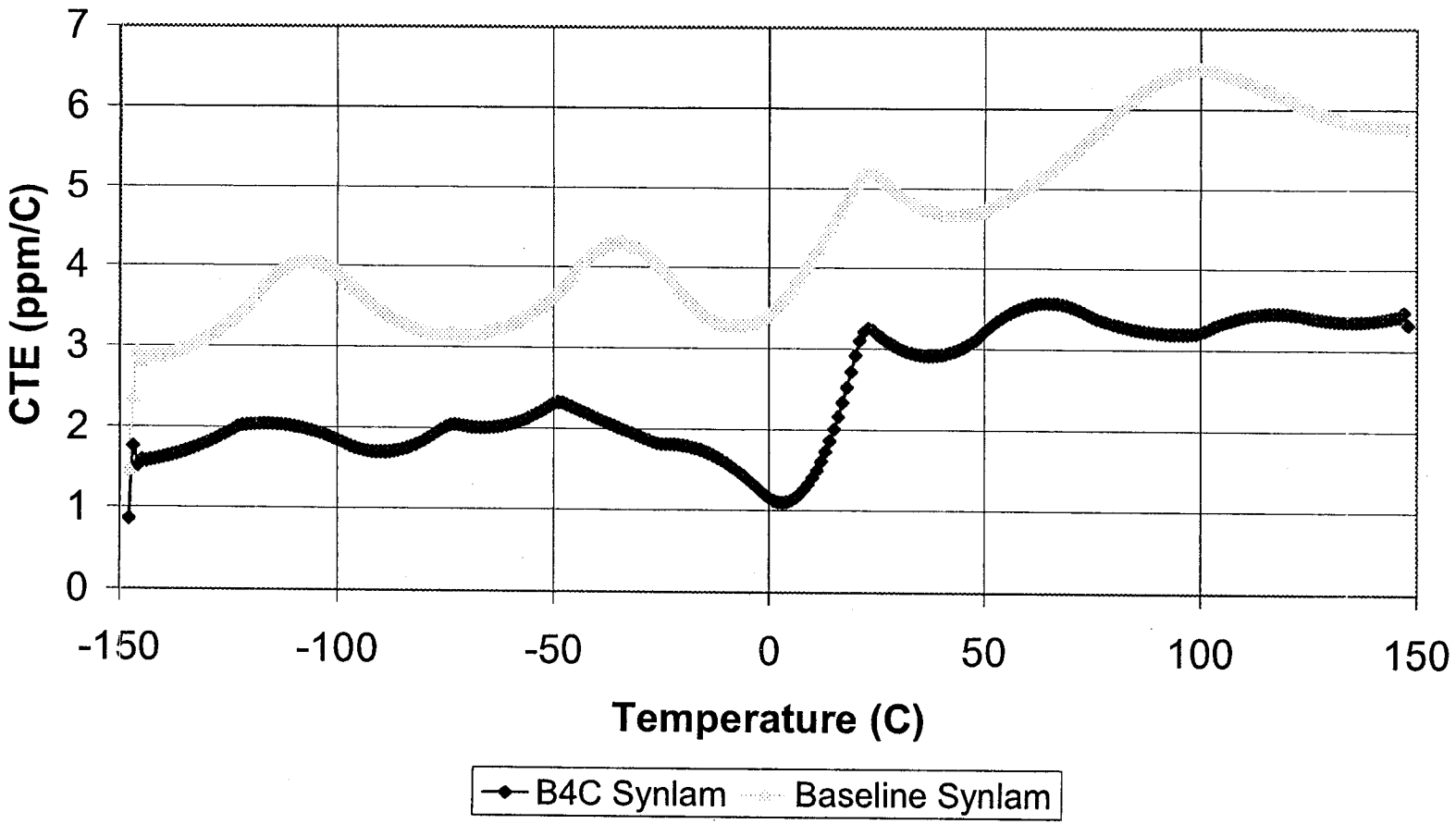
PHASE I RESULTS: CTE Reduction

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



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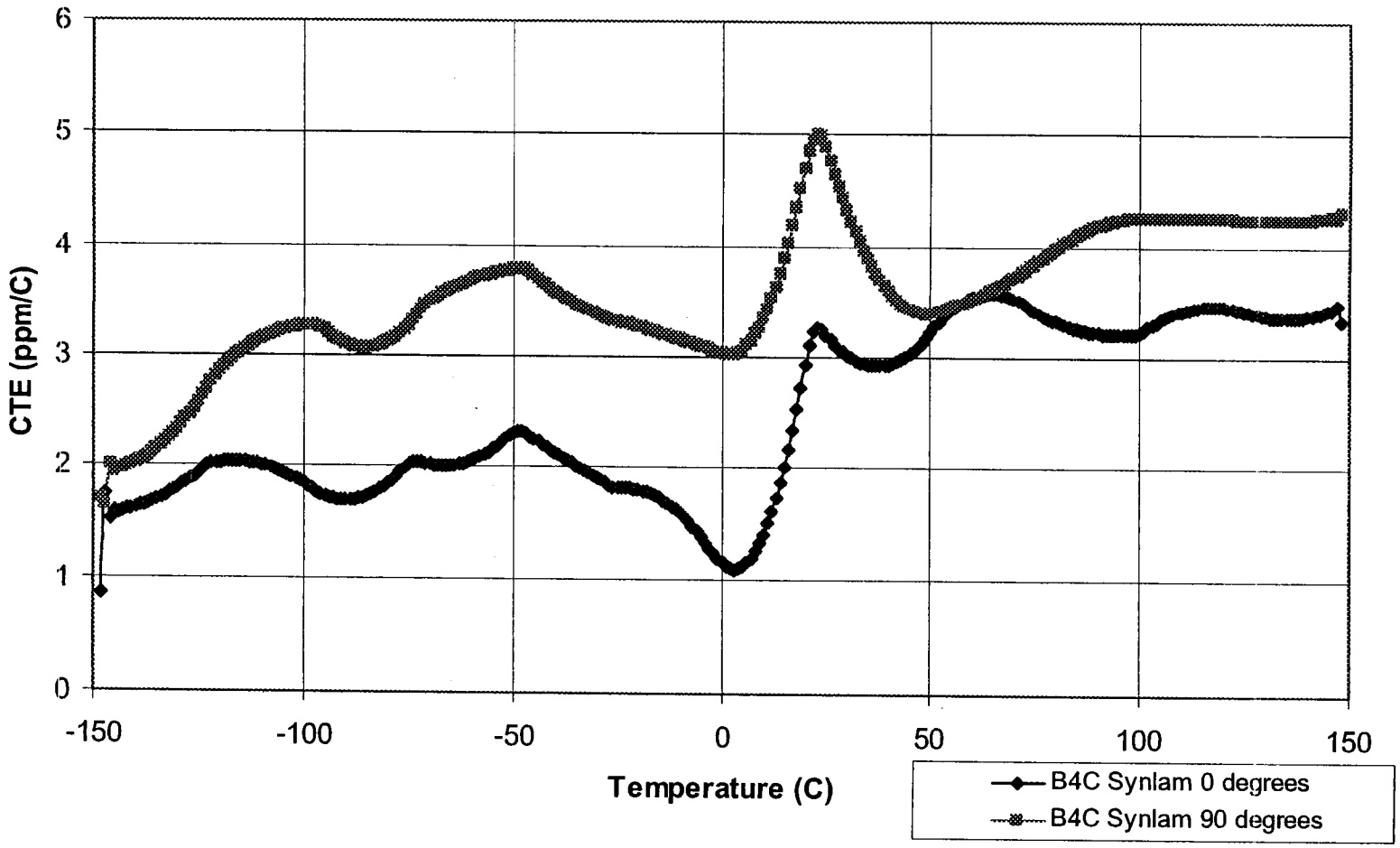
PHASE I RESULTS: Fiber Orientation

CTE Comparison for Along Fibers and Between Fibers of a Synlam



Some Anisotropic Behavior in plane of composite

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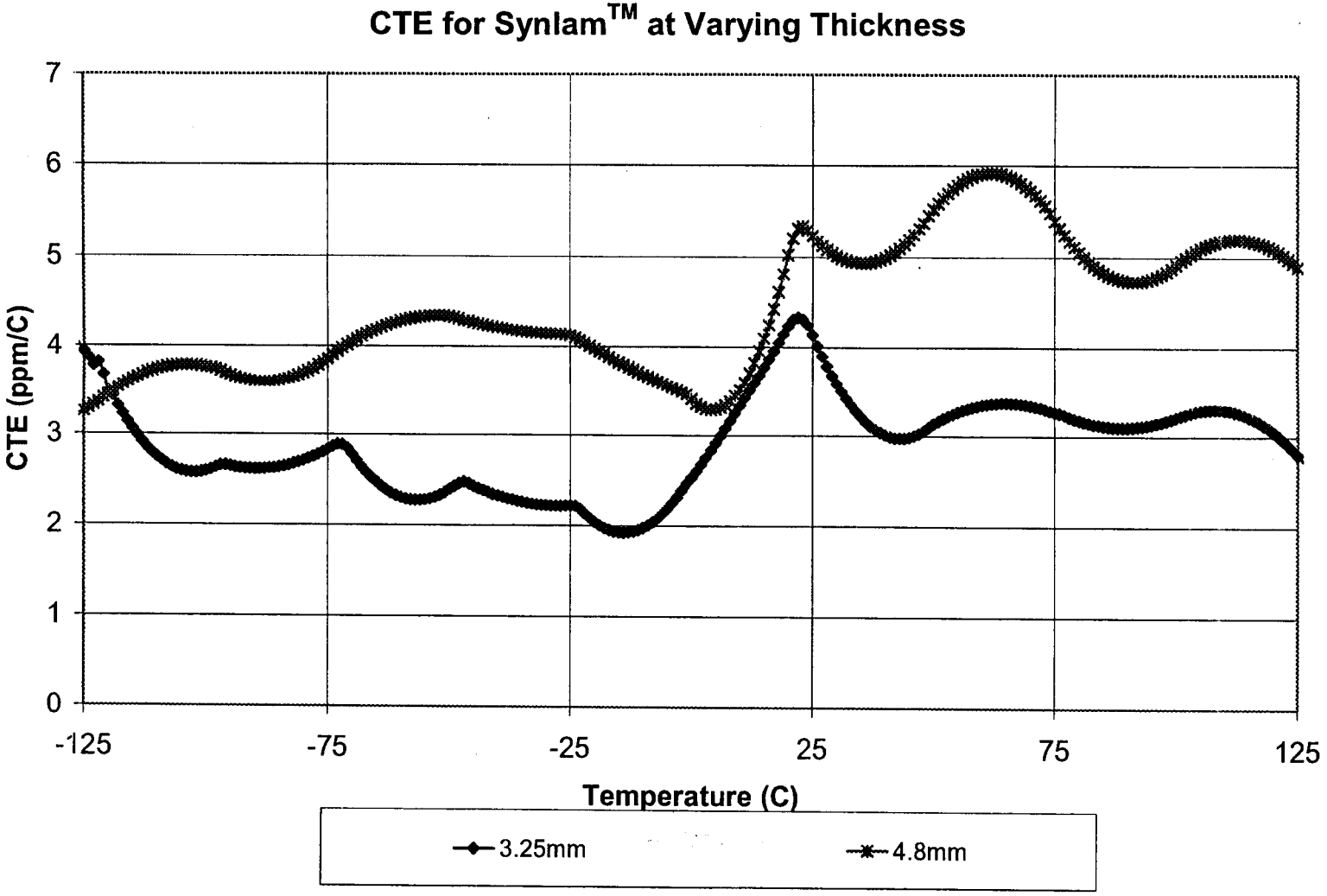
PHASE I RESULTS:



CTE of SynLam™ varying composite thickness

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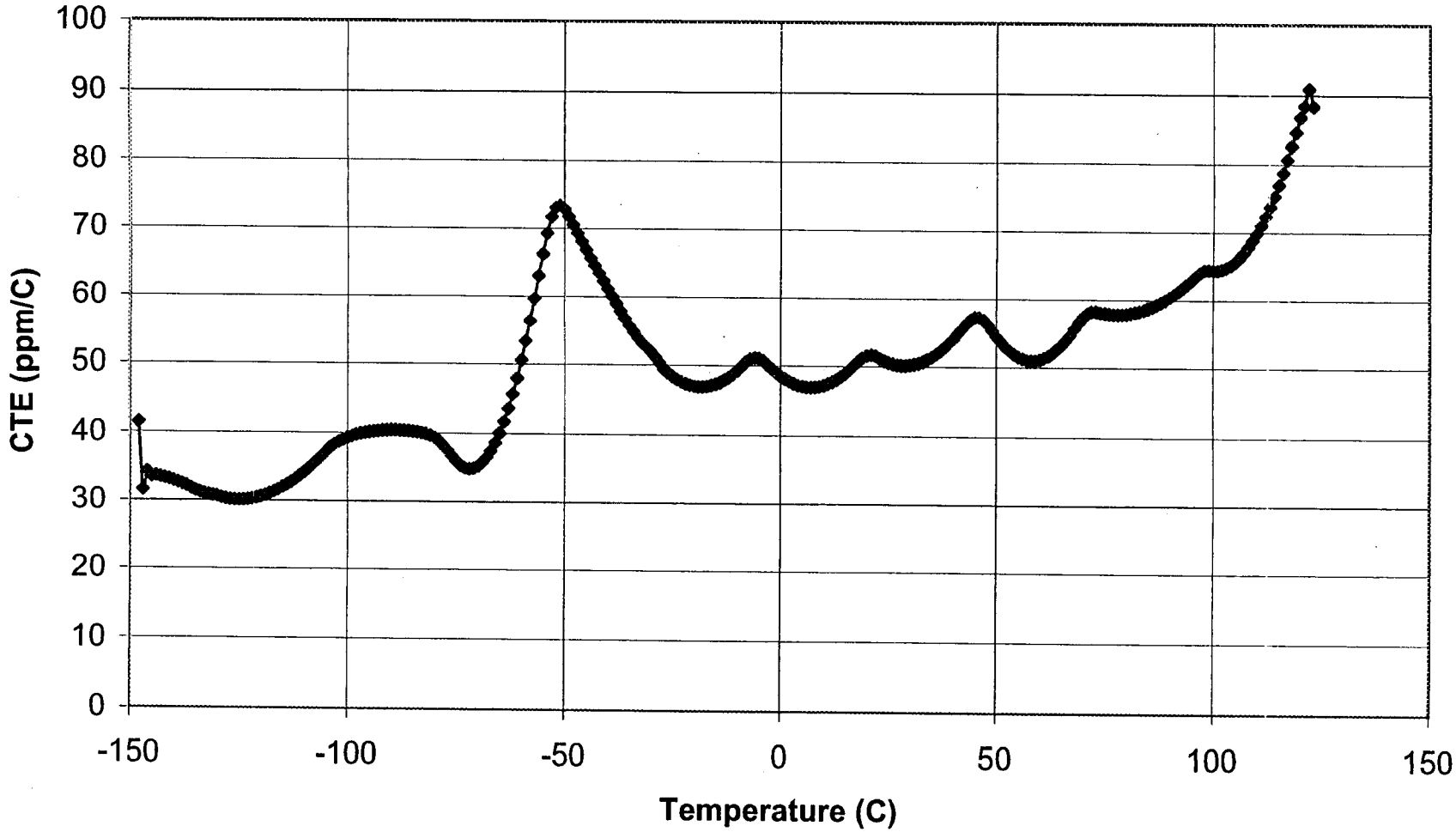
PHASE II RESULTS: Adhesive

Masterbond Supreme 10HT CTE



High CTE of the adhesive adds to rib quilting

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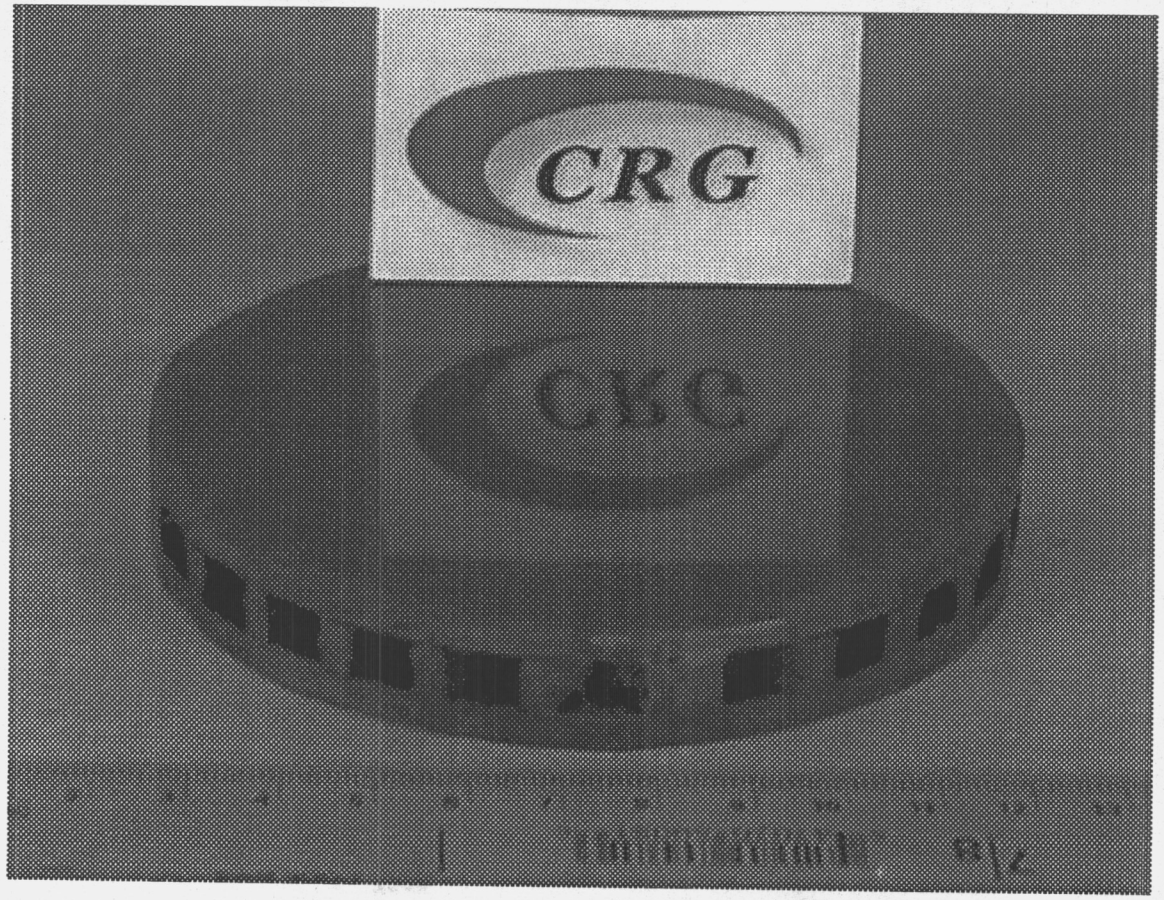
PHASE I RESULTS:
Reflective Surface



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.