Use of Polyimide in IFE Target Components

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Polyimide Film

- Polyimide consists of a large class of aromatic polymers
  - Made by polymerizing a dianhydride and a diamine
  - \( C_{22}H_{10}N_2O_4 \)
- Commercially available polyimide:
  - Films
    - Kapton® (Dupont)
    - Upilex® (UBE Industries)
    - Apical® (Kaneka (was Allied Signal))
  - Bulk
    - Vespel® (Dupont)
Advantages of Polyimide for IFE Targets

• High Strength
  – Luxel Polyimide $\sigma_u \geq 310 \text{ MPa}$
  – Dupont Kapton® Polyimide $\sigma_u \geq 231 \text{ Mpa}$
  – Mylar $\sigma_u \geq 100 \text{ MPa}$
  – Formvar $\sigma_u \geq 60 \text{ MPa}$
  – Polycarbonate (Lexan) $\sigma_u \geq 60 \text{ MPa}$
  – Parylene N $\sigma_u \geq 60 \text{ Mpa}$

  – Strength Measured by Mechanical and Burst Tests:
Advantages of Polyimide Film for Targets (con’t)

- **Large Temperature Range**
  - Used in applications from 1.8K to 400ºC

- **High Radiation Resistance**
  - Gamma Radiation at Savannah River
    - Tests performed on Dupont Kapton®

<table>
<thead>
<tr>
<th></th>
<th>0 Gy</th>
<th>$10^5$ Gy</th>
<th>$10^6$ Gy</th>
<th>$10^7$ Gy</th>
<th>$10^8$ Gy</th>
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<tr>
<td>Tensile (MPa)</td>
<td>207</td>
<td>207</td>
<td>214</td>
<td>214</td>
<td>152</td>
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<tr>
<td>Elongation (%)</td>
<td>80</td>
<td>78</td>
<td>78</td>
<td>79</td>
<td>42</td>
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<tr>
<td>Modulus (MPa)</td>
<td>3170</td>
<td>3280</td>
<td>3380</td>
<td>3280</td>
<td>2900</td>
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- Similar Results for Neutron, Electron, and UV Radiation
Possible Polyimide Components

Heavy Ion Driven Target

- Capsule
- Entrance Window
- Anti-Convection Baffles
- Capsule Support
Polyimide Capsules

• Various Fabrication Methods
  – Vapor Deposited on Mandrels
    • Lawrence Livermore National Lab
    • University of Rochester
    • General Atomics
  – Solution Deposited on Mandrel (Thick Wall)
    • Luxel
    • Solution Deposited Using Ink-Jet
  – Direct Formation Using Bubble (Thin Wall)
    • Luxel
    • Bubble Cured while Acoustically Levitated
Entrance Windows

- Polyimide is Currently used for ICF Hohlraum Entrance Windows
  - NOVA
  - NIF
  - CEA
- Gas Bags Use Polyimide Windows
  - Film is 3500Å Thick
  - 1atm Internal Pressure
- Luxel Routinely Spin-Casts Polyimide Film from 300 to 20,000Å
Optimization of Strength at Cryogenic Temps

- Recently Completed a Project to Optimize the Burst Strength of Polyimide Windows at Cryogenic Temperature
  - Windows From 450 to 9115Å thick
  - Testing at 300K, 77K and 4.2K
  - Optimized Cure Cycle Resulted in Average Burst Strength Increase of 36%
  - Allows Thinner Windows or Higher Internal Pressure
Anti-Convection Baffles

- IFE Hohlraums May Require Anti-Convection Baffles
  - Convection Cells Set Up in Gas
  - Destroy Symmetry Required for Beta Layering
- Current NIF Design Includes Four 1000Å thick Polyimide Baffles
Capsule Supports

- **Current NIF Capsule Supports use Formvar Films**
  - However, DT Filled Capsules Cause the Films to Fail
  - Polyimide is Very Radiation Resistant

- **Heavy Ion Driven Target Capsule Supports**
  - Baseline Assembly Technique is Cryogenic Assembly
  - Shape Required is Too Severe for Flat Film
  - Luxel has Submitted a SBIR Proposal to Develop IFE Capsule Support Mass-Production Methods
Possible Polyimide Components
Z-Pinch Driven Target
Gas Tight Membrane

- Z-Pinch IFE Target Membrane Requirements:
  - Right Circular Cylinder
  - Ultra Thin
  - Leak Tight
  - Low Emissivity
  - High Thermal Conductivity

- Luxel Currently has SBIR Grant to Develop Mass-Production Methods
Summary

• Polyimide’s Unique Properties Offer Many Advantages to IFE Target Designers:
  – Ultra Thin Films
  – High Strength
  – High Radiation Resistance
  – Excellent Cryogenic Properties

• Polyimide Is Available in Many Forms:
  – Thin Films
  – Shapes(spheres, hemis, cylinders)
  – Conformal Coatings