HIGH PERFORMANCE DIELECTRIC MATERIALS DEVELOPMENT

by

J. Piché, Ted Kirchner and K. Jayaraj

Foster-Miller, Inc.
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Waltham, Massachusetts 02154-1196

FOSTER-MILLER, INC.

• 37 year old independent technology development company
• Located in the Boston area
• About 270 employees
• Primary areas of business
  - Advanced polymers
  - Robotics
  - Composites
  - Special machinery
POLYMER COMPOSITES
MATERIALS TECHNOLOGY

• Mission
  - Develop materials and processing technology to meet DoD and commercial needs

• Specific Areas of Research
  - High temperature dielectric materials
  - High performance dielectrics for capacitors
  - Electronics packaging
  - High performance structural materials
  - Micro-composite blends
  - NLO materials, devices
  - Smart processing

HIGH PERFORMANCE
CAPACITORS

• 300°C Filter capacitor for aircraft power conditioning
  - Funded by the U.S. Air Force

• 8 kJ/kg Repetition rated energy storage capacitor - SDIO

• High energy density dielectric film - U.S. Army

• Interpenetrated polymer network capacitor - SDIO (Scheduled to start September, 1991)
HIGH TEMPERATURE AEROSPACE INSULATION

• Identify and develop new insulation materials that can operate reliably at 250°C+
• Phase I SBIR program started in July, 1991
• Funded by the U.S. Air Force
• Monitored by Mr. George Slenski, and Mr. Eddie White

TARGET FOR NEW INSULATION

[Graph showing the relationship between hottest temperature and minimum life for different classes of insulation.]
WHY FOSTER-MILLER?

• Extensive experience in the development of advanced materials for specific DoD applications
  - Thermotropic LCPs, Xydar, Vectra for PWBs
  - Lyotropic LCPs, e.g. PBZT, PBO for capacitors, light weight structures
  - High performance polyimides - electronic packaging
  - Blends of Vectra and LARC TPI
  - Blends of Matramid and PES
  - Interpenetrating networks of PBO, PBZT and polyimide resins, epoxies

• Foster-Miller is not a material vendor
• Design and synthesize novel materials
• Develop techniques to process difficult materials into films for major material producers

• Close working relationship with
  - Resin vendors
  - Cable and wire vendors
  - System houses
  - Airframe companies
  - and leading experts

• Related experience in
  - High temperature dielectrics for capacitors
  - Insulation for electromagnetic launchers
APPROACH

• Phase I
  - Identify key performance parameters and requirements for high temperature insulation materials
  - Prepare an evaluation matrix consisting of appropriate weighted coefficients for each performance parameter
  - Characterize each candidate material with a composite relative merit index (performance index) using the evaluation matrix
  - Select a small number of candidates that meet or exceed all requirements for further investigation

• Phase II
  - Thoroughly characterize selected materials
  - Develop methods to fabricate round and flat wire constructions
  - Evaluate materials in finished wire constructions
  - Pick one for incorporation into an airframe
PHASE I PROGRAM PLAN

REQUIREMENTS/EVALUATION PARAMETERS

- 250°C+ temperature rating
  - Thermal index
- Dry arc resistance
- Voltage withstand, insulation resistance, flammability
- Toxicity, smoke quantity, ... 
- Retention of properties
  - Abrasion, flex life ...
# MATERIALS UNDER CONSIDERATION

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<thead>
<tr>
<th>Material</th>
<th>Source</th>
<th>Advantages and Properties</th>
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<tbody>
<tr>
<td>Fluorinated PBO-PI</td>
<td>Hoechst Celanese</td>
<td>Combines processibility of polyimides with high temperature properties of LCPs</td>
</tr>
<tr>
<td>Thermoplastic PBO with hexafluorinated moieties</td>
<td>Material Lab, WRDC</td>
<td>Thermally processible, high temperature stability, Tg&gt;380°C</td>
</tr>
<tr>
<td>Difluoro-PBZT, tetrakfluoro-PBZT</td>
<td>Foster-Miller</td>
<td>High temperature stability, low dielectric constant</td>
</tr>
<tr>
<td>PQ-100 polyquinolines</td>
<td>Maxdem</td>
<td>Thermally processible, available in a number of configurations, high purity</td>
</tr>
<tr>
<td>PBO-fluorinated IPN</td>
<td>Foster-Miller</td>
<td>High temperature stability combined with resistance to flashover</td>
</tr>
<tr>
<td>PBO</td>
<td>Foster-Miller, Dow</td>
<td>Ultra high thermal stability 300 - 350°C significantly exceeds the performance of Kapton and Tefzel</td>
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<tr>
<td>FPE proprietary aromatic polyester</td>
<td>3M</td>
<td>Readily available high quality aromatic films useful up to 250°C</td>
</tr>
<tr>
<td>Fluorinated polyimides</td>
<td>Hoechst-Celanese</td>
<td>Readily available, from Ube/ICI, DuPont thermal stability exceeds Kapton and Tefzel</td>
</tr>
<tr>
<td>Polysiloxazoneimides</td>
<td>McGrath, VPI</td>
<td>Resistant to ionizing radiation, high thermal stability</td>
</tr>
<tr>
<td>Fluorocarbon-hydrocarbon polymers</td>
<td>Tefzel, DuPont</td>
<td>Readily available, high quality films, moderate thermal stability</td>
</tr>
<tr>
<td>Organo-ceramic hybrid nano composites</td>
<td>Garth Wilkes, VPI</td>
<td>Resistant to ionizing radiation, high thermal stability, greater than 200°C</td>
</tr>
<tr>
<td>Polysilsequioxane</td>
<td>David Sarnoff Labs</td>
<td>Good electrical properties up to 250°C superior to Kapton and Tefzel, can dip or spray coat</td>
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</table>
ADVANCED INSULATION MUST MEET MINIMUM PERFORMANCE INCREASES OVER CURRENT MATERIALS AND BE AMENABLE TO LARGE-SCALE PROCESSING AT ACCEPTABLE COSTS
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| Ahmad Hammoud and Mark W. Stavnes, compilers | National Aeronautics and Space Administration  
Lewis Research Center  
Cleveland, Ohio 44135-3191  |

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<tr>
<td>This document contains the proceedings of the First NASA Workshop on Wiring for Space Applications held at NASA Lewis Research Center in Cleveland, Ohio, July 23-24, 1991. The workshop was sponsored by NASA Headquarters Code QE Office of Safety and Mission Quality, Technical Standards Division and hosted by the NASA Lewis Research Center, Power Technology Division, Electrical Components and Systems Branch. The workshop addressed key technology issues in the field of electrical power wiring for space applications. Speakers from government, industry and academia presented and discussed topics on arc tracking phenomena, wiring applications and requirements, and new candidate insulation materials and constructions. Presentation materials provided by the various speakers are included in this document.</td>
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