HIGH PERFORMANCE DIELECTRIC MATERIALS DEVELOPMENT

by

J. Piché, Ted Kirchner and K. Jayaraj

Foster-Miller, Inc.
350 Second Avenue
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
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
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

<table>
<thead>
<tr>
<th>Material</th>
<th>Source</th>
<th>Advantages and Properties</th>
</tr>
</thead>
<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, tetrafluoro-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>
</tr>
<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, Ube/ICI, DuPont</td>
<td>Readily available, from Ube/ICI, DuPont thermal stability exceeds Kapton and Tefzel</td>
</tr>
<tr>
<td>Polysiloxane-imides</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>
</tr>
</tbody>
</table>
ADVANCED INSULATION MUST MEET MINIMUM PERFORMANCE INCREASES OVER CURRENT MATERIALS AND BE AMENABLE TO LARGE-SCALE PROCESSING AT ACCEPTABLE COSTS
LIST OF ATTENDEES

Bruce Banks
NASA Lewis Research Center
MS 302-1
21000 Brookpark Road
Cleveland, OH 44135

Eric Beamann
NASA Lewis Research Center
MS 301-2
21000 Brookpark Road
Cleveland, OH 44135

Jon Bayless
NASA Kennedy Space Center
MS 301-2
21000 Brookpark Rd.
Cleveland, OH 44135

Bob G. Beam
NASA Goddard Space Flight Center
Mail Code 421.0
Greenbelt, MD 20771

Robert W. Berasaw
NASA Lewis Research Center
MS 301-2
21000 Brookpark Road
Cleveland, OH 44135

David Berkelbile
E.J. Dupont Co.
Specialty Polymers Division
Chesterfield Rd., P.O. 400
Wilmington, DE 19898

Henry W. Brandhorst, Jr.
NASA Lewis Research Center
MS 301-3
21000 Brookpark Road
Cleveland, OH 44135

John Burke
NASA Johnson Space Center
Mail Code EPS
Houston, TX 77058

Frank Campbell
Naval Research Laboratory
Code 4654
Washington, DC 20375

Bob Detwiller
Jet Propulsion Laboratory
MS 188-2
21000 Brookpark Rd.
Cleveland, OH 44135

John E. Dickman
NASA Lewis Research Center
MS 301-2
21000 Brookpark Rd.
Cleveland, OH 44135

Patrick Dillon
Jet Propulsion Laboratory
MS 1-106
21000 Brookpark Rd.
Cleveland, OH 44135

Walter Dinkins
Lawrence Technology
2400 Packer Rd.
Lawrence, KS 66044

Stan Domitz
NASA Lewis Research Center
MS 301-2
21000 Brookpark Rd.
Cleveland, OH 44135

Edgar H. Fay
Sverdrup Technology, Inc.
LeRC Group
2001 Aerospace Parkway
Brook Park, OH 44142

Dale C. Ferguson
NASA Lewis Research Center
MS 301-2
21000 Brookpark Rd.
Cleveland, OH 44135

Wilson F. Ford
NASA Lewis Research Center
MS 301-2
21000 Brookpark Rd.
Cleveland, OH 44135

Robert Friedman
NASA Lewis Research Center
MS 501-2
21000 Brookpark Rd.
Cleveland, OH 44135

Sandra Fries-Carr
WP/AF
WL/POOC
Wright Patterson AFB, OH 45433

Krista Gausd
Auburn University
331 Leach Center
Auburn, AL 36849

Ahmad Hammoud
Sverdrup Technology, Inc.
MS 301-2
21000 Brookpark Rd.
Cleveland, OH 44135

John E. Harbison
NASA Marshall Space Flight Center
MS EP 64
Huntsville, AL 35812

Robert Hendrix
NASA Johnson Space Center
Mail Code EPS
Houston, TX 77058

Bob Jones
TRW, Inc.
One Space Park
Bldg. G1 Rr2400
Redondo Beach, CA 90278

Dennis J. Kaimar
Allied-Apical
P.O. Box 2322
Morristown, NJ 07962-2322

Wassim Khachen
University of Buffalo
312 W. Sonner Hall
Buffalo, NY 14260

Ted Kirschner
Foster Miller, Inc.
350 Second Ave.
Waltham, MA 02154-1195

Javad Laghari
University of Buffalo
Bonner Hall, Room 316
Buffalo, NY 14260

Joe Landers
NASA Marshall Space Flight Center
MS CP 21
Huntsville, AL 35812

Jimmy Lee
NASA Marshall Space Flight Center
MS EE 81
Huntsville, AL 35812

Stan Levin
Allied-Apical
2839 Lombardi Road
Mission Viejo, CA 92692

Larry Linley
NASA White Sands Test Facility
P.O. Drawer M
Las Cruces, NM 88004

Roger Loralle
Aerospace Business Association
3040 Presidential Drive, Suite 201
Fairborn, OH 45324

L. David Massie
WP/AFB
WL/POOC
Wright Patterson AFB, OH 45433

Tamara S. McIntyre
NASA Marshall Space Flight Center
MS EH 02
Huntsville, AL 35812

Billy J. McPeak
NASA Marshall Space Flight Center
MS EB 13
Huntsville, AL 35812

Daniel Mulville
NASA Headquarters
Code QW
Washington, DC 20546

Patrick Murray
Naval Air Systems Command
1421 Jefferson Davis Hwy.
Arlington, VA 22243-4100

Ian Myers
NASA Lewis Research Center
MS 301-3
21000 Brookpark Rd.
Cleveland, OH 44135

John Nainus
WP/AFB
WL/POOL
Wright Patterson AFB, OH 45433

Masao Oku
Allied-Apical
11 Columbia Rd.
P.O. Box 2322R
Morristown, NJ 07962-2322

Joe Pilchci
Foster Miller
165 Bear Hill Road
Waltham, MA 02154

Bruce Pike
Engineering Teledyne Thermals
P.O. Box 909
Elm City, NC 27822-0909

Jeannette Plante
Unisys - NPPO
4700 Boston Way
Lanham, MD 20706-4311

John Reagan
NASA Lewis Research Center
MS 301-4
21000 Brookpark Rd.
Cleveland, OH 44135

Gerald Reuter
NASA Johnson Space Center
Mail Code 3
2101 NASA Road One
Houston, TX 77058

C.R. Sawyer
Boeing Aerospace
P.O. Box 240002
Huntsville, AL 35824-6402

Greg Schmitz
NASA Lewis Research Center
MS 301-102
21000 Brookpark Rd.
Cleveland, OH 44135

Gene Schwarz
NASA Lewis Research Center
MS 301-2
21000 Brookpark Rd.
Cleveland, OH 44135

George Sieniaki
WP/AFB
WL/MSA
Wright Patterson AFB, OH 45433

Ron Solomon
McDonnell Aircraft Co.
Dept. 354
Mail Code 0341240
P.O. Box 516
St. Louis, MO 63166

Tom Stueber
Sverdrup Technology, Inc.
NASA Lewis Research Center
Group MS 302-1
21000 Brookpark Rd.
Cleveland, OH 44135

Gary Sundeberg
NASA Lewis Research Center
MS 301-2
21000 Brookpark Rd.
Cleveland, OH 44135

Jayant Suthar
University of Buffalo
312 W. Bonner Hall
Buffalo, NY 14260

R.V. Peterson
Rockwell International
Mail Code FB 88
P.O. Box 7099
Downey, CA 90241

181
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.