HIGH TEMPERATURE POLYMER DIELECTRIC FILM INSULATION

Robert J. Jones
TRW
Redondo Beach, California

N94-28715

HIGH TEMPERATURE POLYMER DIELECTRIC FILM INSULATION

BACKGROUND

- DUAL USE SYSTEM DRIVERS FOR DEVELOPMENT, QUALIFICATION AND PRODUCTION OF NEXT GENERATION, VERY HIGH TEMPERATURE WIRE INSULATION
  - ENERGY RECOVERY/GENERATION/DISTRIBUTION AND TRANSPORTATION MARKETS (1990's)
  - SUPER CAPACITY/RESPONSE ELECTRONIC COMPUTATION AND TELECOMMUNICATION EQUIPMENT (1990's)
  - HIGH SPEED CIVIL TRANSPORT (NEXT CENTURY)
  - ALL ELECTRIC AIRPLANE (NEXT CENTURY)
- EXAMPLES OF SYSTEM RATIONALE FOR VERY HIGH TEMPERATURE WIRE INSULATION
  - SMALLER, MORE EFFICIENT ELECTRONIC SYSTEMS RUN HOTTER
  - OPERATING ENVIRONMENTS SUCH AS DOWNWELL ARE GETTING MORE THERMALLY SEVERE
  - ACTIVE COOLING SYSTEMS FOR GENERATORS/ALTERNATORS, STORAGE/TRANSMISSION/DISTRIBUTION SYSTEMS AND BLACK BOXES ARE COSTLY AND EQUATE TO SEVERE WEIGHT PENALTIES
  - SMALLER DIAMETER WIRES MAY BE SUFFICIENT TO CARRY EQUIVALENT POWER

HIGH TEMPERATURE POLYMER DIELECTRIC FILM INSULATION

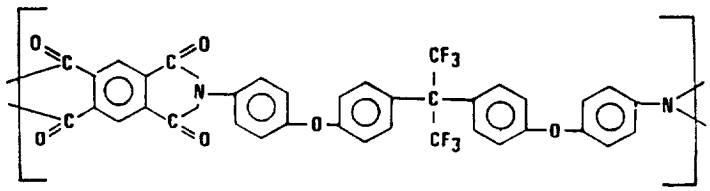
BACKGROUND (CONTINUED)

- ASSESSMENT OF EMERGING REQUIREMENTS HAS DICTATED THAT 300°C PERFORMANCE IS THE GOAL FOR NEXT GENERATION WIRE INSULATION
  - VERY SIGNIFICANT INCREASE OVER CURRENTLY QUALIFIED POLYIMIDE AND FLUOROPOLYMERS RATED AT 200°C (OR SLIGHTLY ABOVE)
  - EMERGING HIGH TEMPERATURE POLYMER MATERIALS HAVE BEEN SHOWN TO HAVE POTENTIAL FOR PERFORMANCE AT $\geq$300°C
  - $\geq$300°C INSULATIONS SHOULD MEET NEW DUAL USE PERFORMANCE REQUIREMENTS WELL INTO NEXT CENTURY
- STATUS OF RECENT OR CURRENT 300°C POLYMERIC WIRE INSULATION ACTIVITY
  - UBE INDUSTRIES OFFERED UPILEX® S FILM, BUT WITHDREW IT FROM THE MARKET IN 1992
  - FOSTER MILLER IS STUDYING LIQUID CRYSTAL POLYMERS
  - 3M IS DEVELOPING FPE POLYMER MATERIAL
  - TRW HAS SHOWN HIGH PROMISE FOR ITS PFPI POLYMERS UNDER USAF SPONSORSHIP (FINAL REPORT WL-TR-91-2105); FURTHER WORK WILL BE CONDUCTED IN RECENTLY AWARDED USAF CONTRACT F33615-93-C-2367

HIGH TEMPERATURE POLYMER DIELECTRIC FILM INSULATION

TRW PFPI AS SUPERIOR 300°C POLYMER CANDIDATES

- REPRESENTATIVE CHEMISTRY



US PATENT NUMBERS 4,111,906; 4,196,277; 4,203,922; 4,880,584

(PFPI POLYMERS WERE INVENTED UNDER NASA LEWIS RESEARCH CENTER SPONSORSHIP IN THE LATE 1970's)

- VERSATILITY
  - FORMULATIONS CAN BE TAILORED TO MEET PRODUCT USE REQUIREMENTS
  - COATING VARNISH, FILM AND POWDER PRODUCT FORMS CAN BE EMPLOYED TO ADAPT FORMULATIONS TO EXISTING PROCESSING EQUIPMENT FOR CONVERSION TO WIRE INSULATION
  - POLYMERS POSSESS SUPERIOR COMBINATION OF THERMAL/ELECTRICAL/UV, MOISTURE & FLUID RESISTANCE/TRIBOLOGICAL PROPERTIES
  - FILMS ARE AMENABLE TO CERAMIC COATING FOR LEO ATOMIC OXYGEN PROTECTION

HIGH TEMPERATURE POLYMER DIELECTRIC FILM INSULATION

TRW PFPI AS SUPERIOR 300°C POLYMER CANDIDATES (CONTINUED)

- COMPARISON OF PROMISING PFPI FILM PROPERTIES WITH KAPTON® (FROM REPORT WL-TR-91-2105)

PROPERTY MEASURED	PROPERTY RESULT[A]	
	KAPTON FILM	TRW PFPI FILM
ELECTRICAL		
• DIELECTRIC CONSTANT		
- AT 25°C	3.1	3.1
- AT 300°C	2.8	2.9
• DISSIPATION FACTOR		
- AT 25°C	0.001	0.001
- AT 300°C	0.063	0.004
• BREAKDOWN VOLTAGE AT 25°C (V/MIL)		
- AC	7000	6000
- DC	11000	12000
LOW TEMPERATURE STABILITY (CRYOGENIC)		
• EXPOSURE IN LIQUID NITROGEN AND HELIUM	NO EFFECT	NO EFFECT
AIR AGING AT 300°C		
• WEIGHT LOSS AFTER 1000 HRS (%)	13.0	4.1
HUMIDITY AGING AT 90°C/100% RH		
• WEIGHT LOSS AFTER 1200 HRS (%)	FAILED AFTER 500 HRS	0.4
BASIC SOLUTION (PH, 10) AGING AT 93°C		
• WEIGHT LOSS AFTER 96 HRS (%)	2.6	1.3
ULTRAVIOLET LIGHT AGING AT 25°C		
• WEIGHT LOSS AFTER 1000 HRS (%)	6.7	1.4

A) ALL PROPERTIES DETERMINED ON 0.001-INCH THICK FILMS

HIGH TEMPERATURE POLYMER DIELECTRIC FILM INSULATION

TRW'S PFPI AS SUPERIOR 300°C POLYMER CANDIDATES (CONTINUED)

- PROMISING BULK POLYMER OR COATING PROPERTIES

PROPERTY TYPE	PROPERTY MEASURED	TEST RESULT
THERMAL	• MELTING POINT	≥400°C
	• GLASS TRANSITION TEMPERATURE	>300°C
TRIBOLOGICAL	• FRICTION COEFFICIENT	0.3-0.6(RT); 0.1-0.2 (300°C)
	• WEAR RATE	MUCH LOWER THAN TEFLON
COATING ENVIRONMENTAL RESISTANCE	• COATING INTEGRITY AFTER EXPOSURE TO:	
	- 500 HRS, 343°C	NO BLISTERING OR LOSS OF ADHESION
	- 21 DAYS, 71°C IN MIL-H-5606 HYDRAULIC FLUID	
	- 21 DAYS, 71°C IN MIL-L-7808 JET ENGINE OIL	
	- 2000 HRS, 25°C IN 5% SALT SPRAY	

HIGH TEMPERATURE POLYMER DIELECTRIC FILM INSULATION

TRW'S PFPI AS SUPERIOR 300°C POLYMER CANDIDATES (CONTINUED)

- DUAL USE CHALLENGES FOR 1994-1996 TIME FRAME
  - CONTINUING USAF WORK
    - •• VERIFY PROMISING INITIAL FILM AND COATING PROPERTIES AS A WIRE INSULATION
    - •• DEMONSTRATE A SUPERIOR 300°C ADHESIVE FOR WRAPPED FILM
    - •• ACHIEVE HIGH INSULATION RESISTANCE TO ARCING & TRACKING
    - •• ACHIEVE FACILE FILM WRAP PROCESSABILITY ON EXISTING PLANT EQUIPMENT AND PRODUCE HIGH QUALITY INSULATED WIRE
  - COMMERCIAL PRODUCT DEVELOPMENT
    - •• QUALIFY AND INTRODUCE PFPI INTO MAGNET WIRE INSULATION, AUTOMOTIVE COMPONENT COATING AND MEDICAL DIAGNOSTIC PRODUCT APPLICATIONS
    - •• MAXIMIZE HIGH VOLUME USE APPLICATIONS TO MINIMIZE FUTURE POLYMER COSTS
- PROPOSED ADAPTATION OF PFPI TO MEET FUTURE NASA 200°C SPACE SYSTEM WIRE INSULATION REQUIREMENTS
  - DETERMINE INITIAL BASELINE WIRE PROPERTIES SPECIFIC TO SPACE APPLICATION ON COATED OR WRAPPED WIRE
  - TAILOR EXISTING 300°C POLYMER CANDIDATE TECHNOLOGY, AS REQUIRED, TO OFFER OPTIMUM 200°C PERFORMANCE; BUILD UPON EURECA SAMPLE TEST RESULTS
  - PRODUCE OPTIMIZED INSULATED WIRE AND PERFORM QUALIFICATION TESTS FOR GENERAL AND MISSION SPECIFIC SPACE APPLICATIONS