DuPont Automotive Performance Materials to Help Electrify Vehicles

Hitoshi Shioya
Segment Leader - Asia Pacific
Paul J Kane
North America

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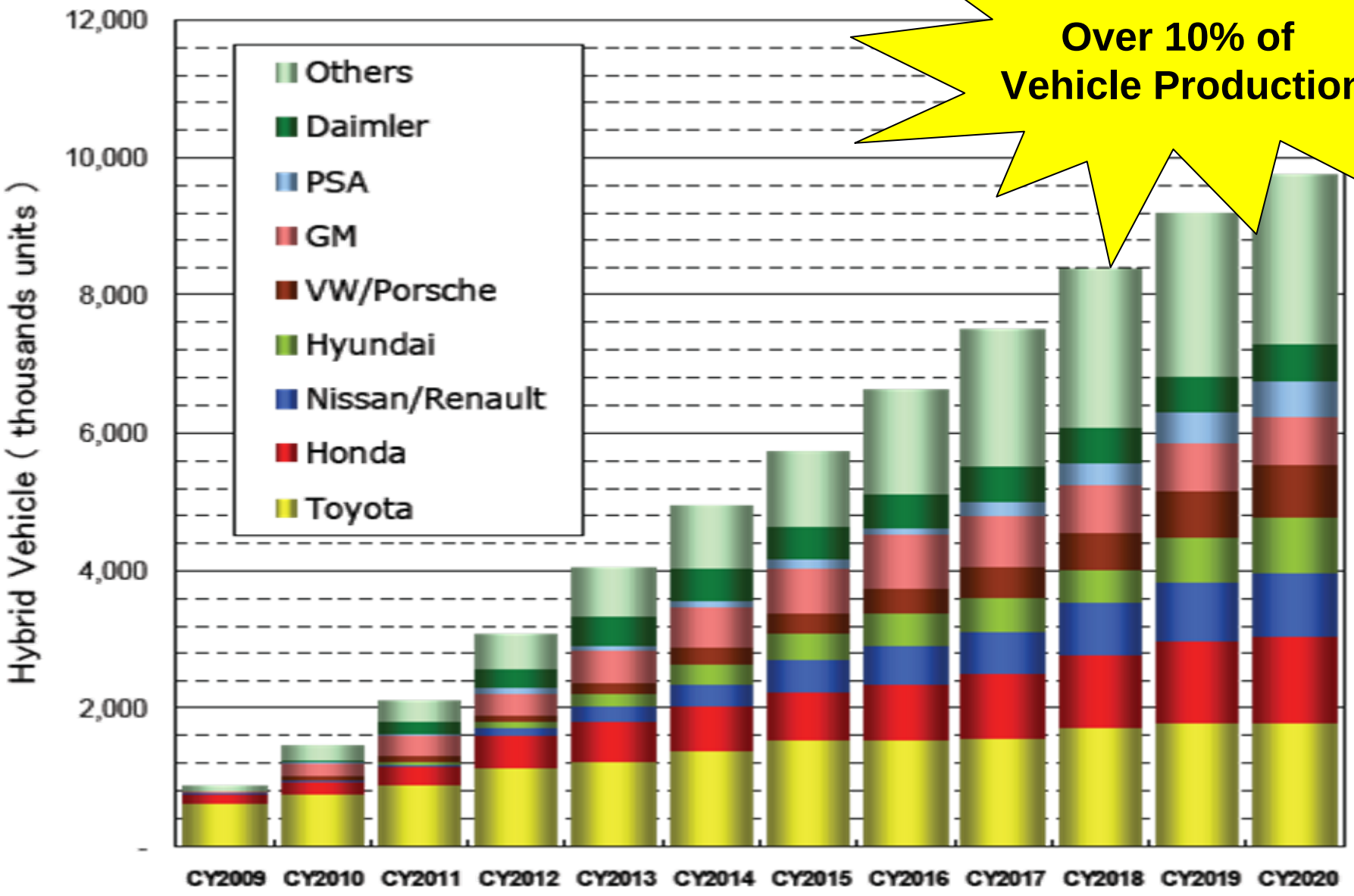
HV/EV market forecast



CY2020

Estimated by HIEDGE 2009

Materials to Help Electrify Vehicles

Requirements:

Reduce mass

- **Extra 200/kg mass of HEV components**

Temperature

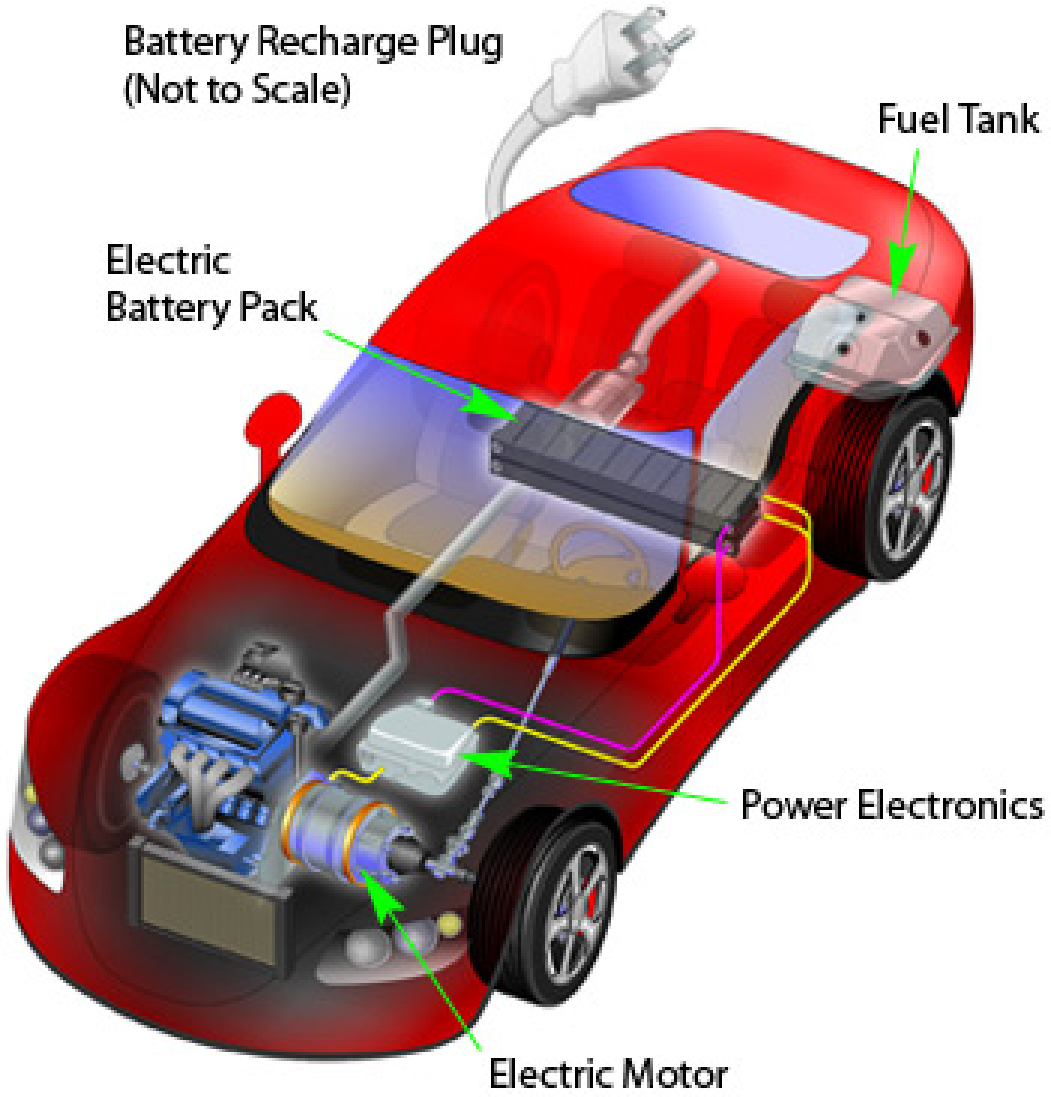
- **40° C to 170° C**

Electrically Isolative

- **Di-electric strength**
- **Di-electric constant**
- **Volume resistivity**
- **EMI shielding-hybrid materials**

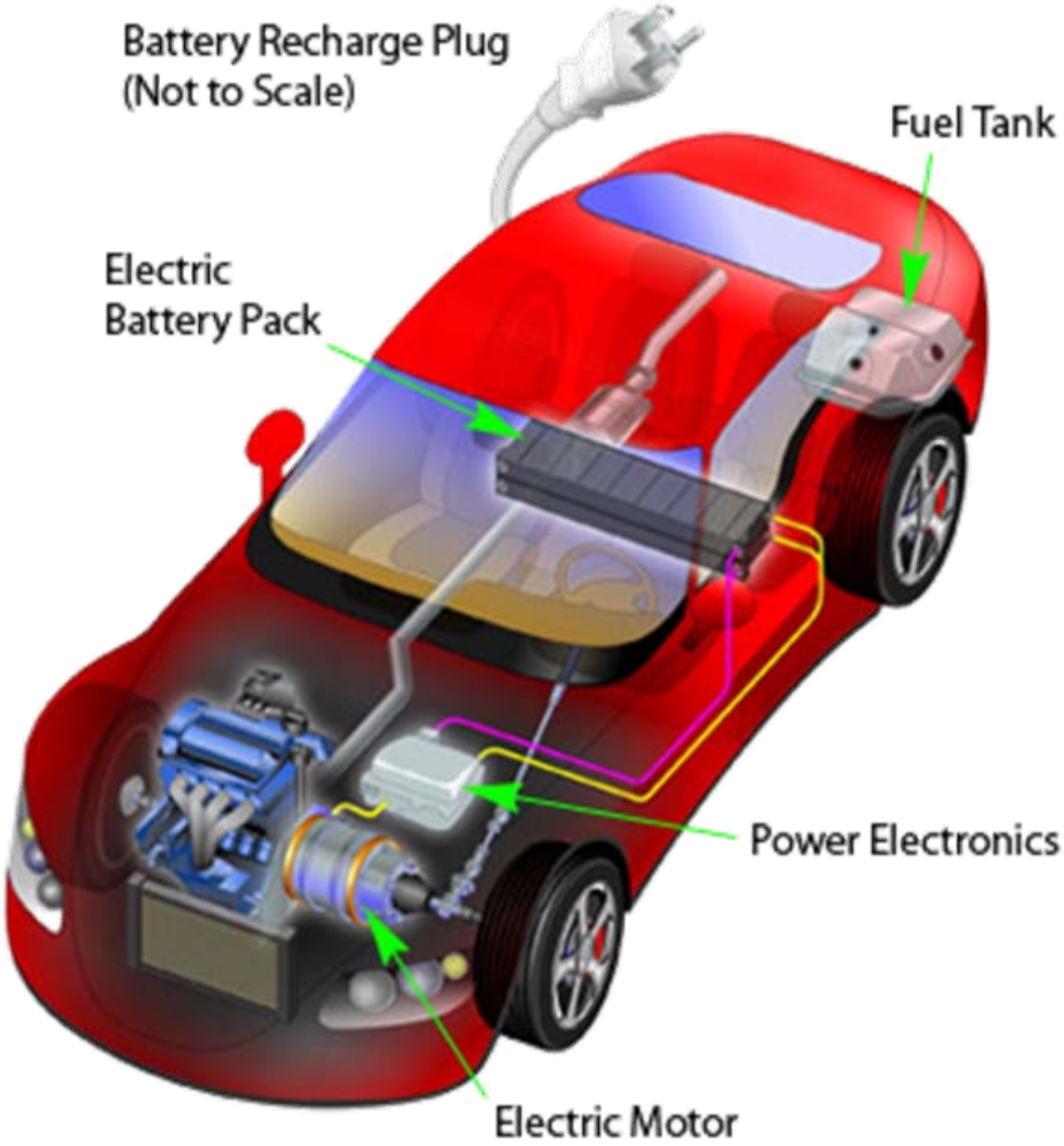
Thermal Management

- **Chemical Resistance (eg. LLC)**
- **Hydrolysis Resistance Thermally Conductive**



Graphic source – U.S. Department of Energy

HEV/EV Components



Graphic source – U.S. Department of Energy

Electric Battery Pack

Electric Motor/Generator

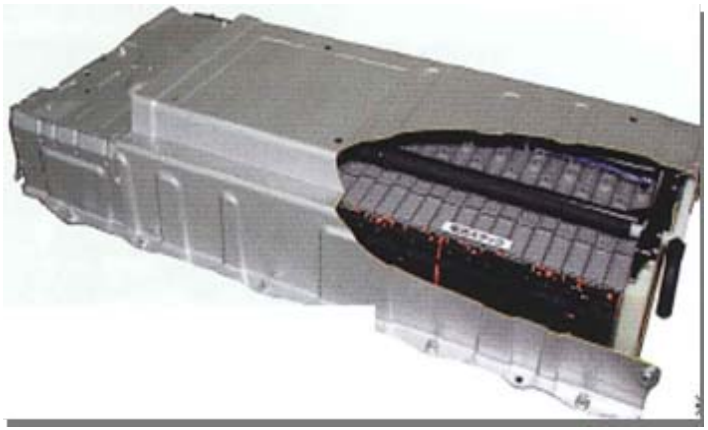
Power Electronics

- **ECU, Inverter, etc.**

High Voltage Connection Systems

Thermal Management Systems

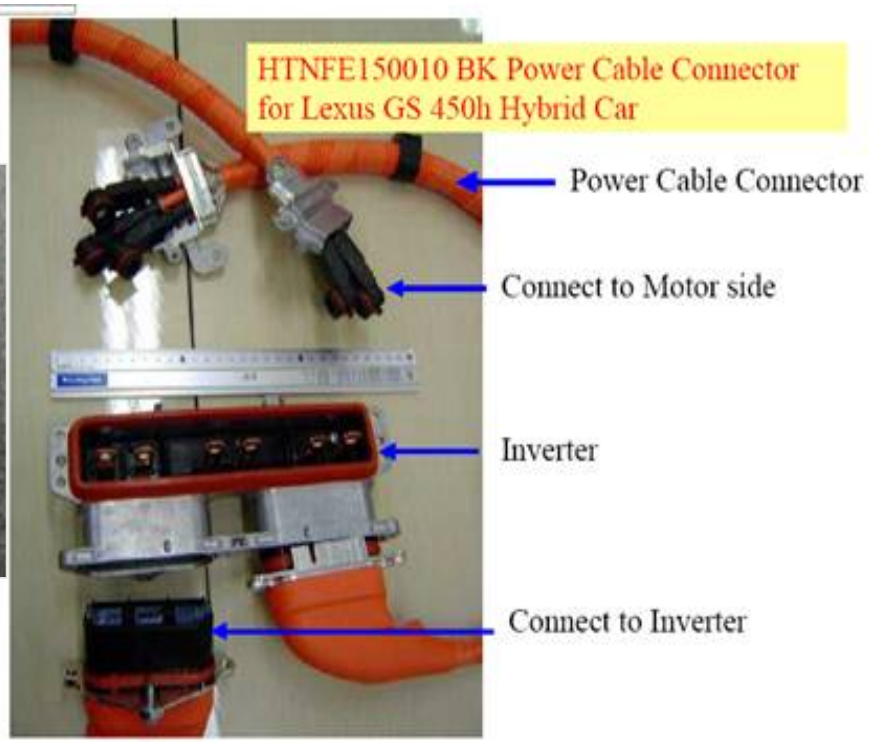
Reduce 200kg in the 3 Major Systems



Inverter – *the hot spot* Motor power control Battery's voltage step up DC/DC converter	**Battery** – *keep it within operating temperature* Energy storage	**Motor** –*insulate better, boost efficiency* Generator Power source

Toyota Prius

Next Generation Inverter – Challenge to Reduce Mass and Cost via Parts Integration



IGBT

Lead frame

Connectors/Cables

High-Energy Cables and Connectors

- **High temperature thermoplastic elastomer DuPont™ ETPV, Hytrel®**

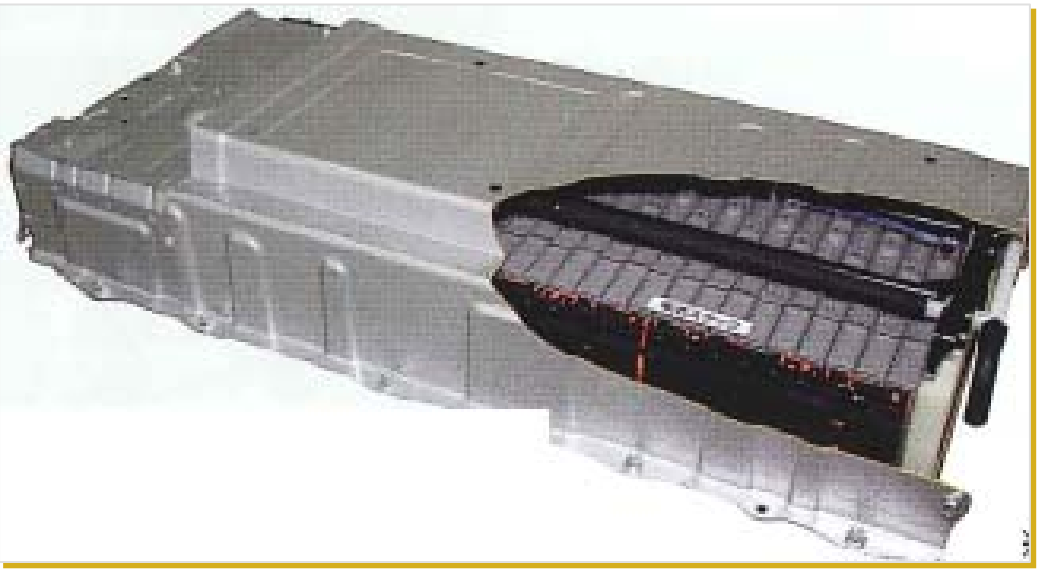
Power Control/Inverter Module Housings and Connectors

- **High temperature PPA**

Over-mold Electrical Lead Frames

- **Leak free paths for coolant (indirect coolant exposure to electronics)**

Next Generation Battery Pack – Challenge to Reduce Mass, Cost and Boost Performance



Frames and Structures
Cell Separators
Electrolyte, Electrodes and Binders

- **Top temperature operating range of 40° - 60° C still requires dimensionally stable LLC resistant materials for structures**
  - **Zytel® HTN 54G35 HSLR is a prime candidate for exposure to moisture/coolant in battery thermal management system**
- **Higher temperature cell separator membranes are coming from DuPont – better barrier properties and lower ionic resistance**
- **R&D effort on improved electrolyte, electrodes, binder materials**

Next Generation Motors – Challenge to Reduce Mass, Cost and Boost Performance

Magnet wire insulation

Connectors and bus bars

Rotor magnet encapsulation

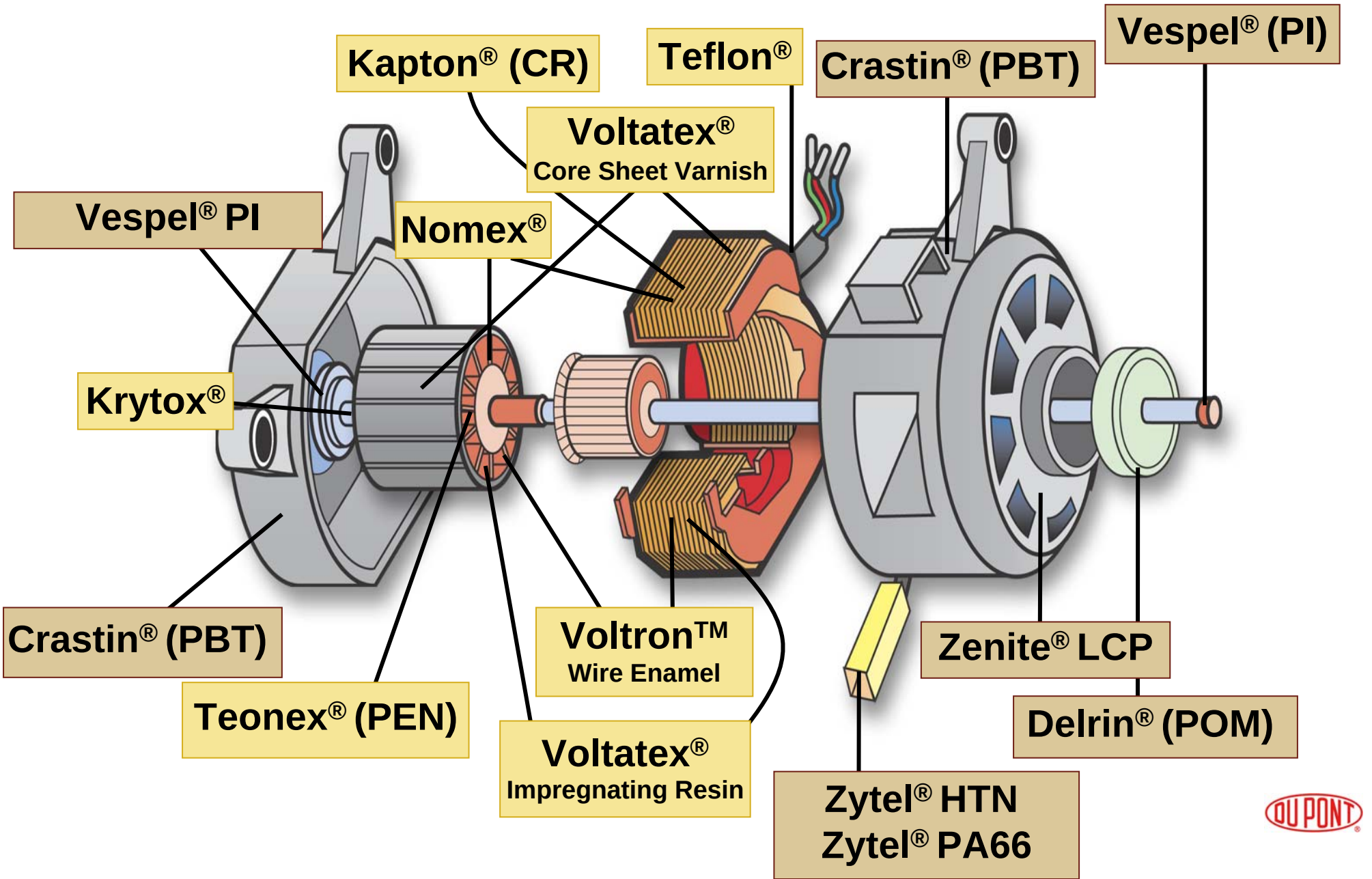
Connectors and encapsulations -high ATF resistance, low creep, USCAR Class 5 (170° C) capability

- **Zytel® HTN (PPA) - best combination of ATF resistance and electrical properties**

Rectangular (flat) magnet wire calls for special insulating systems

- **Proven insulating systems available for wire coatings, slot liner materials, etc.**

DuPont Polymer Use In A Motor – Example



New Materials Driven by New Requirements

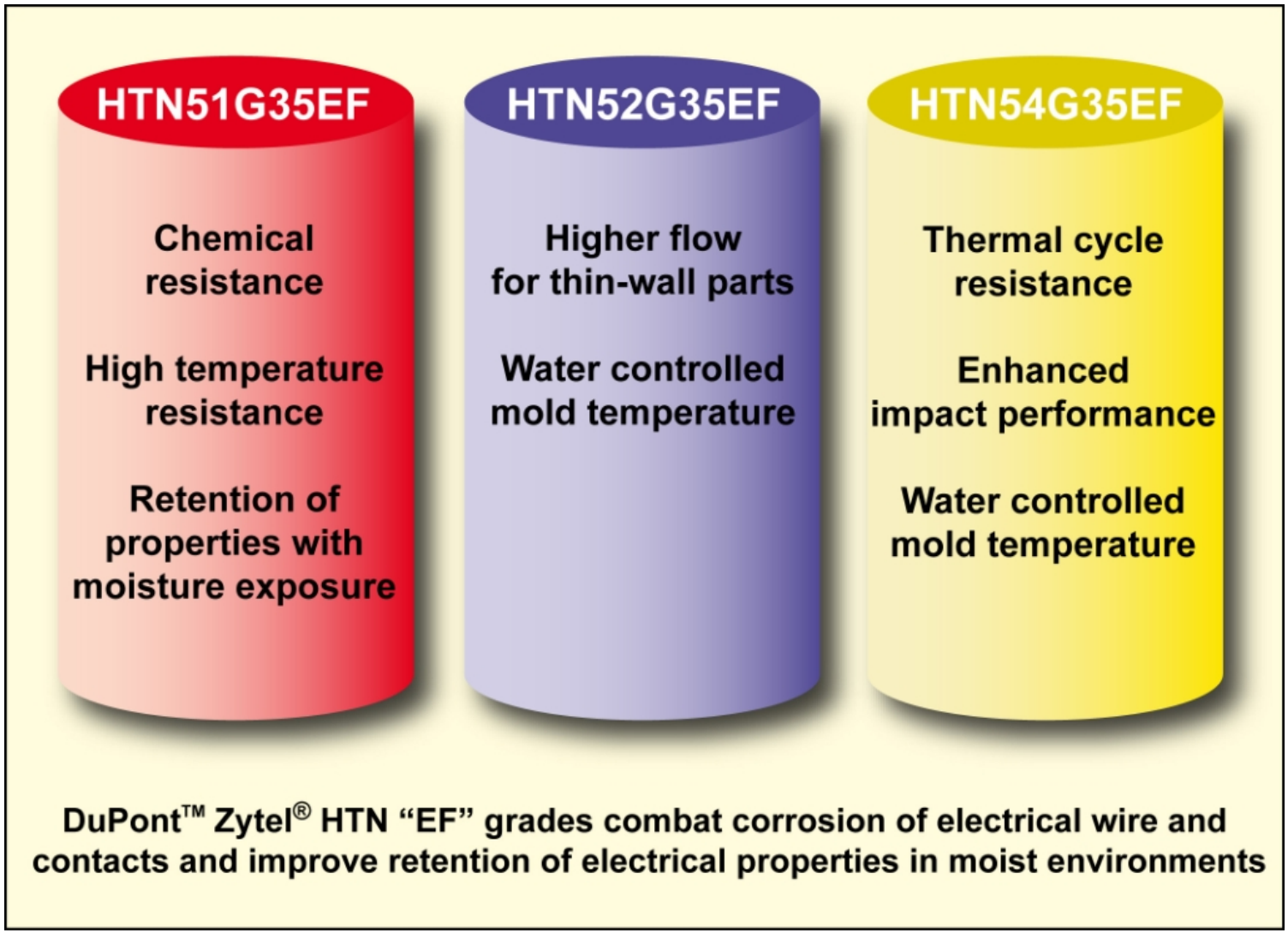
Introducing a New Class of PPA Materials for High Voltage Connection Systems

EF - PPA

“Electronic/Electrically Friendly ”

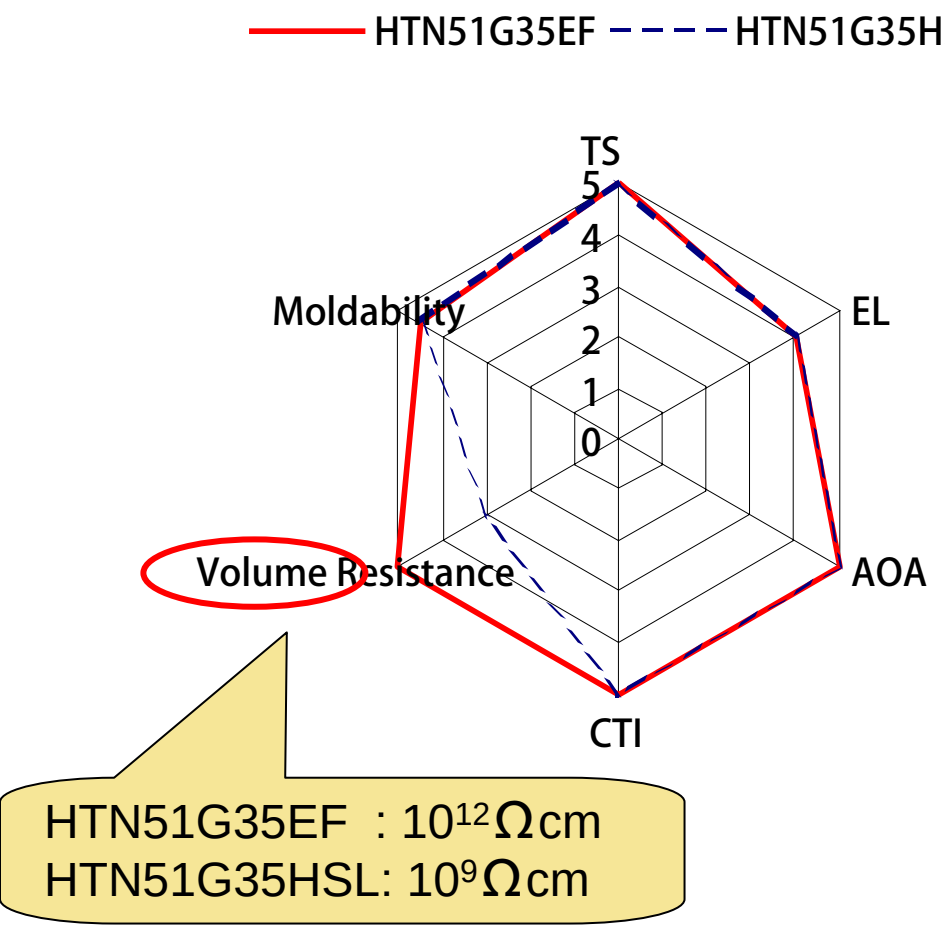
- **Isolation Resistance**
- **Highest CTI 600 V**
- **Well balanced Mechanical Properties**

New DuPont™ Zytel® HTN Grades Combat Corrosion of Electrical Wire, Contacts

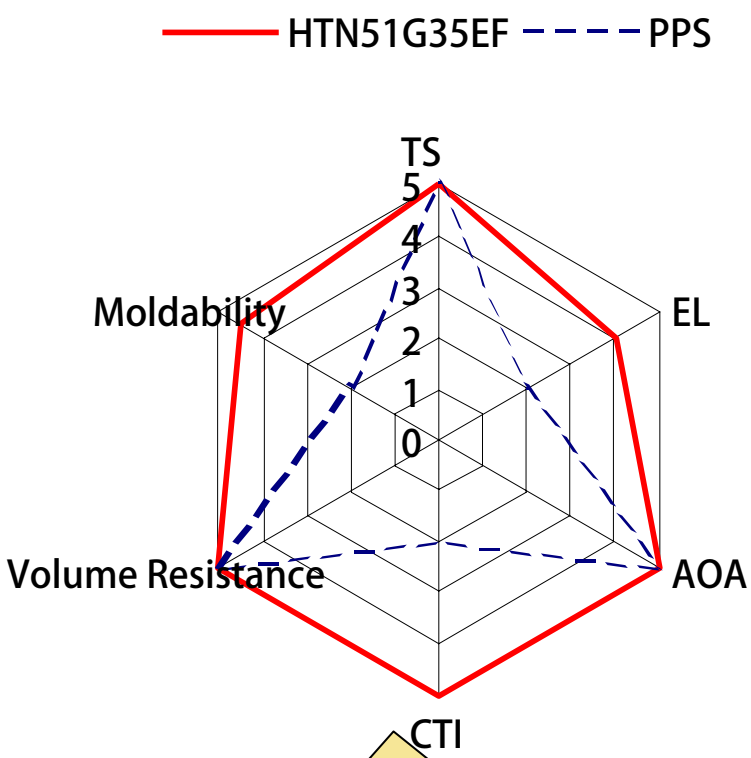


DuPont™ Zytel® HTN "EF" grades combat corrosion of electrical wire and contacts and improve retention of electrical properties in moist environments

HTN51G35EF improves Electrical Performance



HTN51G35EF : $10^{12}\Omega$cm
HTN51G35HSL: $10^{9}\Omega$cm



HTN51G35EF : 600V
PPS : 150V

Spider charts compare HTN51G35EF with PPS

‘EF’ Meets High Voltage Needs

Polymer Type	PPA	PPA	PA66	PPS
Trademark (DuPont)	Zytel® HTN51 (EF Grades**)	Zytel® HTN51	Zytel®	
Glass Transition Temp, Tg (oC)	140	140	80	85
Volume Resistance @ 150 oC	1 E+11	1 E+9	1 E+6	1 E+13
Tracking Index, CTI	600V	600V	400V	150V
Applications	Structural, Electrical, High voltage	Structural, Electrical	Structural, Electrical	

** EF = Electrical / Electronics Friendly Technology

TRACKING RESISTANCE (comparative tracking index) V (Volt)

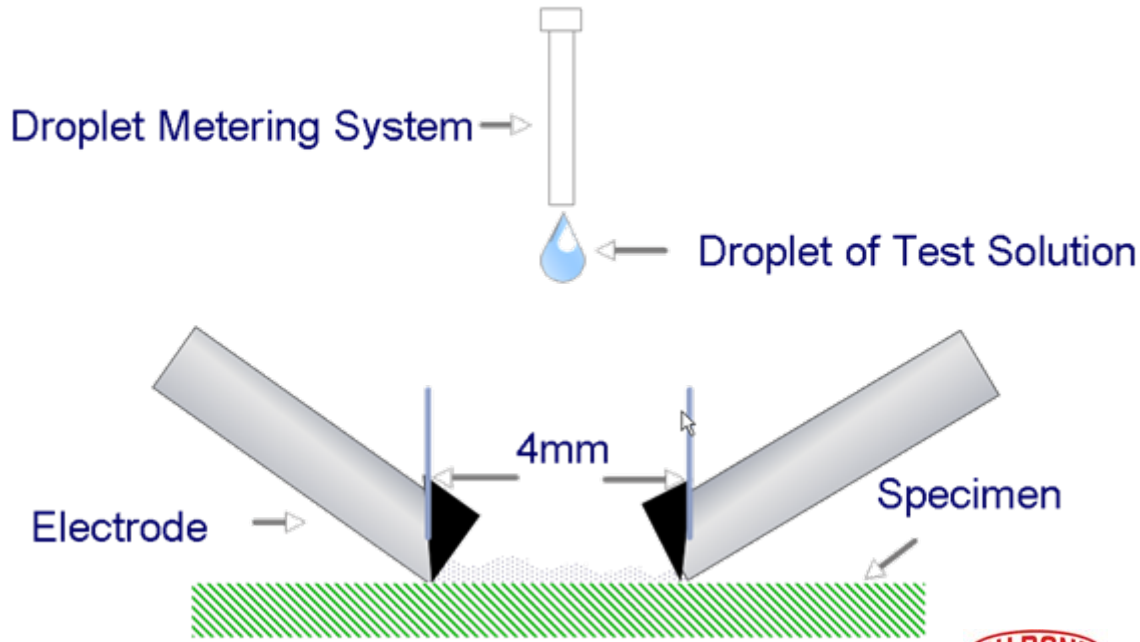
Definition

Tracking is the current flowing on the surface of an insulator between two electrodes caused either through pollution or degradation of the insulator. Tracking resistance is the ability of an insulator to prevent such currents.

Arc tracking is affected by temperature, humidity, carbon particles, dirt, oil and other contaminants on the surface of the insulator. Changing the design of the plastic part can correct arc tracking problems, improving cleanliness or increasing the distance between the electrodes (creepage line).

High CTI is Crucial to Minimize Arcing Damage	
Resin	**CTI (volts)**
PPA (HTN) - EF	600+
40% GR PPS	150
30% GR PBT	450

Comparative Tracking Index (CTI)



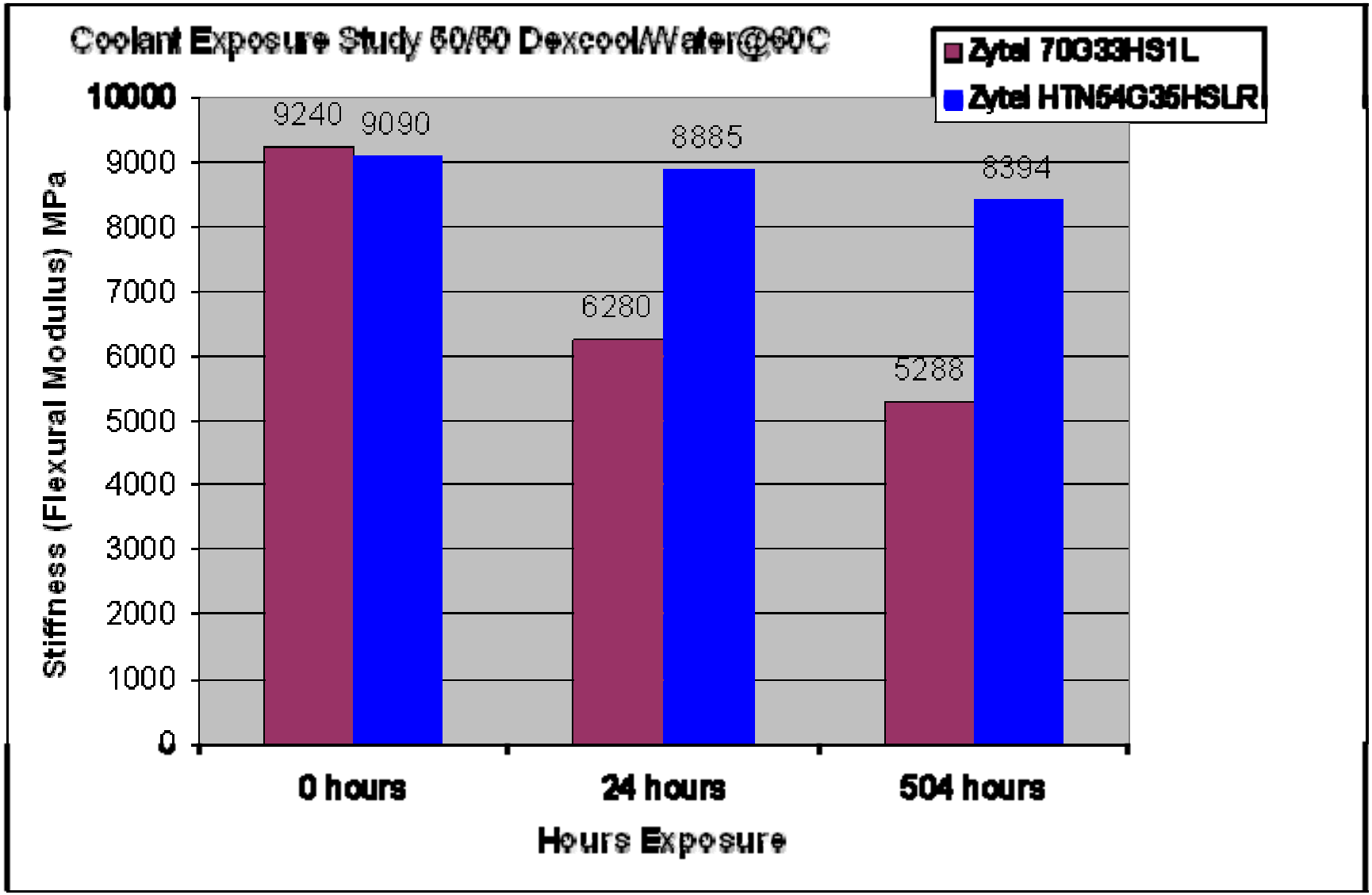
Next Generation EV Thermal Management System – Challenges of Space and Cost

Integrating cooling circuits to manage ICE, HVAC, high temperature electronics, cool and heat the battery

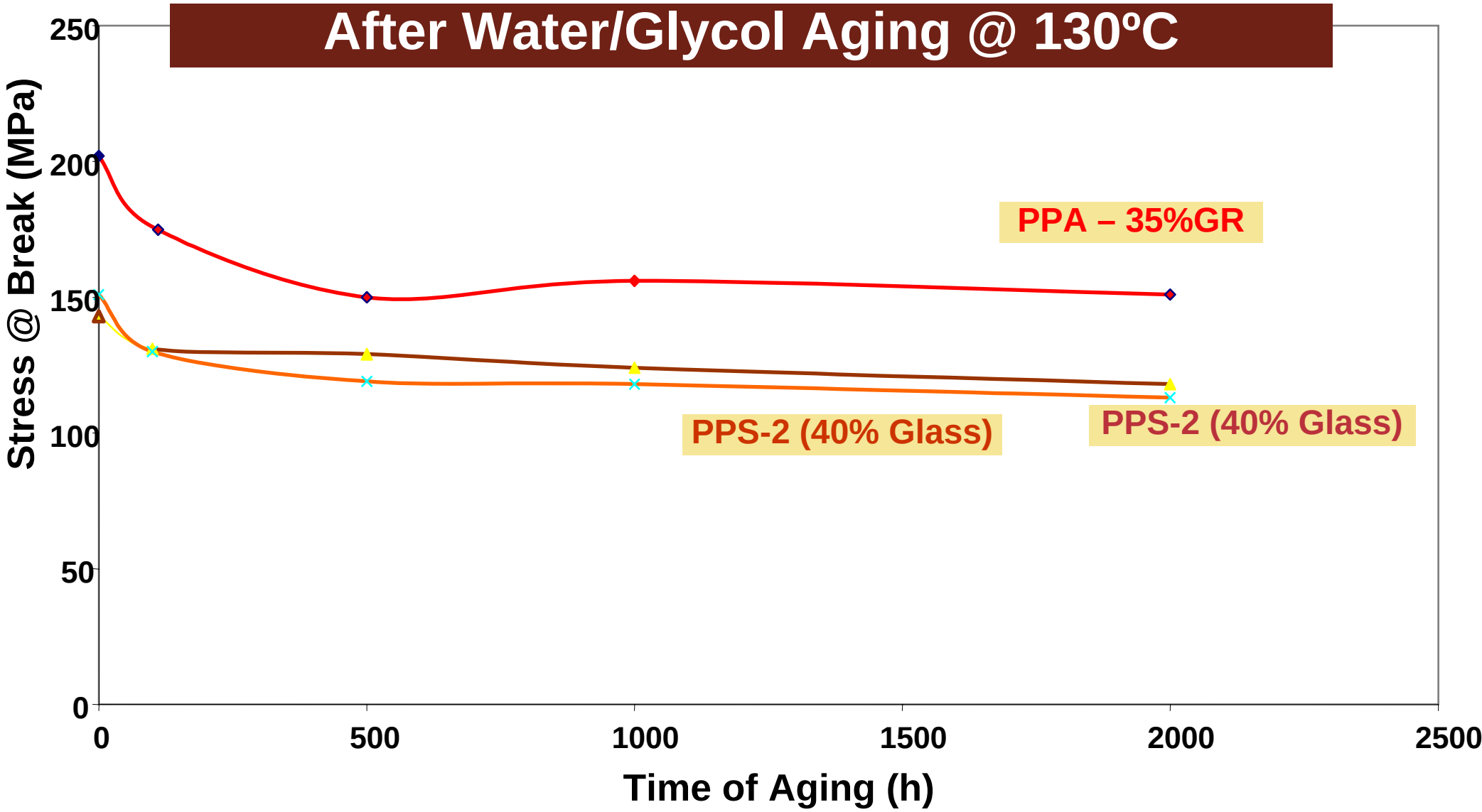
- **Electrical Coolant Pumps, impellers, valves**
- **Thermostats**
- **Surge tanks**
- **Hose, tubing**
- **Electronic controls**

Imagine a multi-functional manifold to integrate and condense the entire system to feed and manage temperatures of each circuit individually

Improved Long Life Coolant Resistance



PPA Retains Properties in Hot Coolant

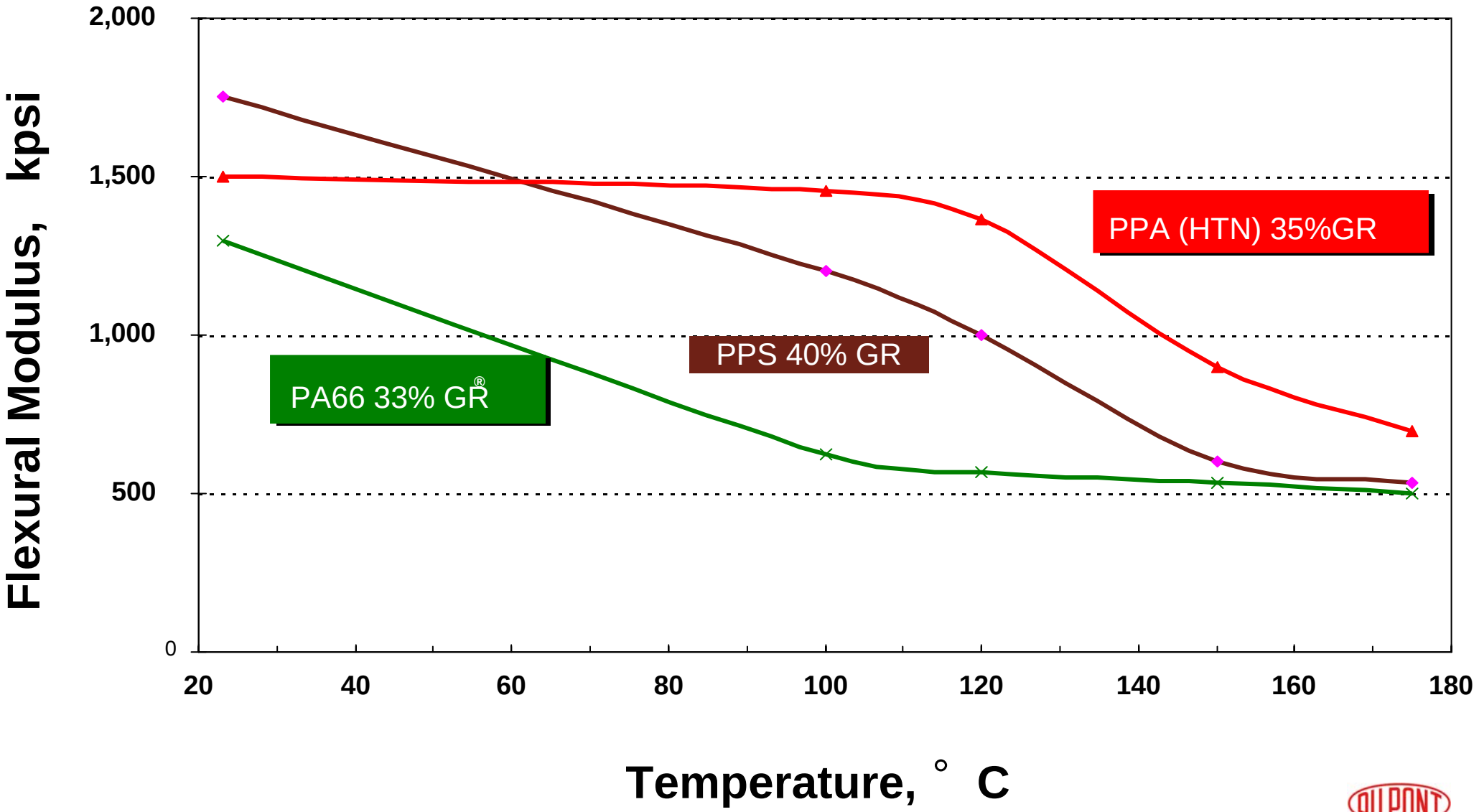


PPA Withstands Demanding EV Challenges

Polymer	PA 66	PPA (HTN)	PPA (HTN)	PPS
Glass Content	33%	35%	45%	40%
Tensile Strength, MPa DAM 50% RH	 200 140	 220 210	 235 230	 175
Elongation, % DAM 50% RH	 3 4	 2.4 2.1	 2.2 2.0	 1.4
Tensile Modulus, MPa DAM 50% RH	 10,500 8,000	 12,500 12,500	 15,000 15,000	 14,000 (Flexural)
Notched Izod Impact, kJ/m2 DAM 50% RH	 13 13	 11 10	 11 10	 8
Specific Gravity	1.39	1.47	1.57	1.68

Property Case for Using PPA in Demanding EV applications

PPA Maintains Rigidity, Strength at High Temperatures, critical for coolant tubes, channels



Polymer Solutions for Hybrid Vehicles

High Voltage Connectors

- Zytel® HTN “EF” (electrically friendly resin)

Power Electronics

- Special DuPont polymers for over molded lead frames for power inverter
- DuPont solutions for indirect cooling of power electronics

Li-ion Battery systems

- Zytel® HTN for dimensional stability, coolant resistant for liquid cooled battery system
- Zytel® “EF” resins for critical electronic over molding to monitor battery cells
- DuPont Flame Retardant Resins (UL-V0)

Electric Motor and Generators

- Zytel® HTN for permanent magnet retention

Materials to Reduce Friction – *Get Power to the Ground*

Dave Ritchey

Global Transportation Segment Leader, DuPont™ Vespel®

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