

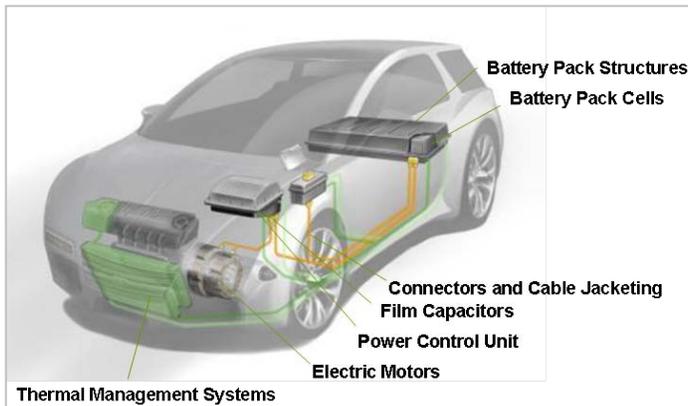


Fact Sheet

DuPont Materials and Technology for Hybrid and Electric Vehicles

Charging the Future of Electric-Powered Vehicles

Every major global vehicle manufacturer offers a hybrid-powered or – *soon* – a plug-in hybrid or battery-electric vehicle to help reduce carbon emissions and dependence on petroleum.



Adoption forecasts vary, depending on the cost of crude oil and amount of government regulation/subsidies, but no one doubts this technology will play an important role in shaping how vehicles are powered. Several industry forecasters predict that, by 2020, power-split hybrids and full electrics could account for 20% to 25% of global vehicle production. The number of vehicle models is expected to increase from 20 to 60 or more by the middle of this decade.

Materials and polymer science play a critical role in cost-effectively developing safer, lighter, more

energy dense battery systems. DuPont – with a broad range of materials, polymer science capabilities and application knowledge to understand the interrelationship of materials – is focusing energies for the following challenges:

Energy Density and Power

- Boost kilowatt-per-hour and power capabilities with improved battery chemistries and materials for critical binders and DuPont™ Energain™ separators.
- Prevent electrical discharge with improved insulation systems that draw from the broadest array of material choices.

Weight and Packaging

- Reduce weight by up to 40% using plastics instead of aluminum and steel.
- Invite component and functional integration that reduces space and improves packaging using high-performance polymers and elastomers.

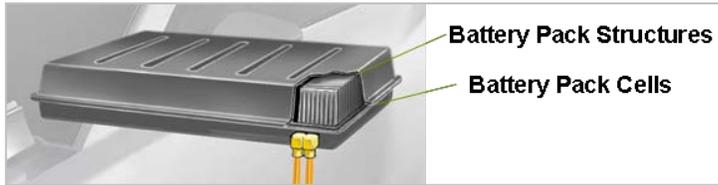
Safety

- Energain™ separators for high performance lithium ion batteries can improve safety by providing stability at high temperatures.
- Protect batteries with new materials that include higher voltage, reduced flammability electrolyte technology and electrode materials to reduce battery heating.
- Improved battery pack performance with flame retardant materials - DuPont™ Nomex® brand paper or pressboard and USCAR-rated thermoplastic materials for 650-volt system requirements.

Thermal Management

- Maintain “sweet spot” operating temperatures (0°C to 55°C) while protecting against highs and lows (-40°C to 120°C) through integrated thermal management systems with materials that resist exposure to coolant and automatic transmission fluid.

Highlights of three active DuPont development programs:



1 - Improving energy density, power, safety while reducing weight in battery pack cells and structures.

Battery Pack Cells

The run for higher power and energy density translates to increased power availability and driving range – a critical differentiator for vehicle manufacturers.

- Now commercially available, DuPont™ Energain™ separators for high performance lithium ion batteries can boost power by 15% to 30%, improve safety by providing stability at high temperatures so hybrid vehicle drivers can drive longer on a single charge, and reach their desired speed more quickly and safely.

Battery Pack Structures

Higher power and energy density challenges the upper performance limits of some materials. Battery packs and power delivery systems, in particular, require protection from exposure to high-voltage systems as well as electrical isolation and thermal conductivity – something neither metals nor plastics have been able to do alone.

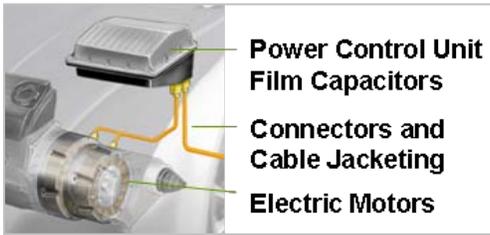
At the same time, power-split hybrids can carry an extra 400 lbs. (200kg), which increases fuel consumption by 1.2 miles per gallon (0.41/100km). A 4-foot to 5-foot battery pack impinges the interior, making it imperative to combine functions to save space with lighter weight materials.

Lightweighting:

- High-performance plastics, including DuPont™ Zytel® HTN PPA resins and new Zytel® PLUS nylon resins offer up to 40% lower mass than aluminum, long life, coolant resistance and the flexibility needed for thermal management and the design freedom to enable parts integration and improve packaging to save space and component cost.
- High performance plastics also provide cost advantages over metals by significantly lowering tooling costs for high volume production.

Added protection in more challenging environments:

- “Electrically friendly” resins – flame retardant, V-0, UL rated Zytel® nylon resins and Zytel® HTN PPA resins with CTI above 600 volts.
- Hydrolysis- resistant, USCAR Class IV capable Crastin® PBT resins.
- Integration of Nomex® aramid fiber for heat and flame resistance.



2 - Efficiently converting, delivering and using power while improving safety, reducing weight in power control units, film capacitors, electric motors and connectors and cable jacketing.

Power Control Unit – TPIM/ Power Inverter Module

This unit controls the power conversion and steps up current when more power is required.

- Protection from electrical magnetic interference is critical so future systems to replace welded aluminum for the housing could include a complete injection molded piece using high-temperature and coolant resistant Zytel® HTN PPA resins combined with other technologies
- Bi-polar gate transistors that convert power and step up voltage can be housed in high temperature-resistant materials, such as a Zytel® HTN PPA resins.
- New “electrically friendly” materials combat the ionic corrosion of copper wires and terminal leads, offer excellent electrical isolation and a very good balance of mechanical properties for component integrity.

Film Capacitors

- High-temperature Teonex® PEN film can reduce size, production times and improve power over a broad temperature range. Ultra-thin DuPont™ Kapton® polyimide films are under development, which may lead to even higher temperature operation, if needed.

Electric Motors

More than a dozen high performance materials converge to help convert energy to power to drive the transmission or vehicle.

- Particularly for traction motors –Voltatex® VS wire enamel coating and high temperature resistant Kapton® tape for inverter grade magnet wire provide design engineers high performance solutions to resist damage in use and interference from corona/magnetic fields, a major challenge in EV motor applications.
- New environment-friendly Voltatex® One Component Impregnating Resins for HEV / EV-motors are a key component of modern motor production. They turn the laminated core and the wire winding into a homogenous and mechanically stable unit. The impregnated motor shows excellent thermal and mechanical strength with extreme long term stress endurance, outstanding electrical properties and depending from the design increase of Partial Discharge Inception Voltage (PDIV) and better heat dissipation.
- Slot liners of Nomex® brand papers and other materials are used where the magnet wire is difficult to keep separated and to insulate the stator from the rotor where the magnets are located.
- DuPont™ Vespel® Parts & Shapes can be used in thrust washers, seal rings, bushings and wear pads to manage friction, reduce weight and help protect housings and sensors from damage due to wear.
- Power connectors in hydrolysis resistant, heat stabilized, “electrically friendly” Zytel® HTN PPA resins offer excellent resistance to long term exposure to automatic transmission fluid, often used to cool motors that generate temperature peaks of 170°C).

Connectors and Cable Jacketing

Plastics that offer added protection in higher voltage environments

- Several new “electrically friendly” Zytel® HTN PPA resins and DuPont™ Crastin® PBT resins have been developed with comparative tracking indices above 600 volts to help prevent electrical arcs and sparks in connectors.

- New flame retardant V-0 UL94-rated Zytel® HTN PPA resins and Crastin® PBT resins for inverters, power cable connectors linking the battery to the inverter to the motor.
- DuPont™ Vamac® AEM and DuPont™ ETPV for high energy cable insulation.



3 - Streamline thermal management systems to integrate function, simplify manufacturing, reduce weight and especially cost.

Integrating existing HVAC and powertrain cooling systems with electric vehicle power systems thermal management could simplify as many as five independent cooling circuits now required – with redundant pumps, thermostats, surge tanks, hose and tubing and electronic controls – into one or two “manifolds” that manage the systems together.

- Zytel® HTN PPA resins can offer 1/3 lower moisture absorption rate versus glass reinforced nylon 66 and excellent long life coolant resistance and superior mechanical properties with coolant and humidity exposure.
- Demonstrated long-term thermal system component life shown through more than 20 applications, such as thermostat housings, water pumps, charge air coolers and coolant inlets and outlets made of Zytel® HTN PPA resins, many of which are on the road around the world after more than 10 years.

DuPont materials and polymer science for use in safer, lighter, more efficient energy storage options for hybrid and electric vehicles:

- New Energain™ separators for high performance lithium ion batteries.
- High Performance Polymers for battery pack structures; power control units; connectors and cable jacketing, electric motors and thermal management systems - Zytel® HTN PPA resins, Zytel® PLUS nylon resins, DuPont™ Vespel® parts and shapes, Crastin® PBT resins.
- DuPont Electrical Insulation systems for electric traction motors – Nomex® brand papers, Kapton® polyimide films, Voltatex® VS wire enamels and Voltatex® resins and varnishes.
- DuPont™ Vespel® Parts & Shapes can be used in thrust washers, seal rings, bushings and wear pads to manage friction, reduce weight and help protect housings and sensors from damage due to wear.
- High Performance elastomers for battery systems, cable jacketing and thermal management systems – Vamac® AEM and DuPont™ ETPV.
- Kapton® polyimide film insulation for cylindrical cells.
- DuPont Teijin Films (PET and Teonex® PEN) separators for film capacitors.

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High resolution images are available at hybrid-electric.automotive.dupont.com