Driving AHEAD™ with Innovative Materials

Nate Brese, Marketing Fellow, and Rozalia Beica, Global Director Strategic Marketing
Presentation Outline

- Electronic Market Trends
- Automotive Trends
- DuPont AHEAD™ Materials
- DuPont Advanced Packaging
2017 Global Electronics Ecosystem

- **Electronic Devices**: $2 Tr
- **Semiconductors**: $410 Bn
- **Materials**: $48 Bn
- **Equipment**: $56 Bn

**Global GDP**: $78 Tr
(3.2% Global growth in 2018; 6.7% for China)

- **Automotive Global Sales**: $2.3 Tr
  3% of WW GDP

**Electronics global sales**: $2 Tr
2.5% of the world GDP

Source: SEMI, Prismark, Yole, IHS Markit
Key Semiconductor Growth Markets & Drivers

Market Growth 2016-2021 ($Bn)

- Communications: $129B (2021)
- Industrial: $51.6B (2021)
- Automotive: $46.1B (2021)
- Data Processing: $141B (2021)
- Consumer: $40.9B (2021)
- Mil/Aerospace: $4.6B (2021)

Data source: Gartner 2017

CAGR2016-2021 (%)

- Communications: 6.9%
- Consumer: 4.0%
- Mil/Aerospace: 2.1%
- Data Processing: 3.1%
- Automotive: 8.8%
- Industrial: 2.0%

2021 Market size
Key Semiconductor Growth Markets & Drivers

- **Communications**
  - Market Growth: $154B (2022)
  - CAGR: 6.9%

- **Consumer**
  - Market Growth: $50.3B (2022)
  - CAGR: 4.0%

- **Data Processing**
  - Market Growth: $178B (2022)
  - CAGR: 3.3%

- **Automotive**
  - Market Growth: $64.5B (2022)
  - CAGR: 10.5%

- **Industrial**
  - Market Growth: $66.5B (2022)
  - CAGR: 10.1%

- **Mil/Aerospace**
  - Market Growth: $5.84B (2022)
  - CAGR: 2.1%

- **Consumer**
  - Market Growth: $50.3B (2022)
  - CAGR: 4.0%

Data source: Gartner 2017 & 2018

2021/2022 Market size
Mega Trends are Transforming the Automotive Market

Energy Efficiency - Electrification
- Hybrid/ EV
- Battery
- Plug-in
- Charging infrastructure
- Fuel efficiency
- Light weight

Automation & Safety
- Assisted driving
- Lane keeping support
- Emergency braking
- Adaptive cruise control
- Traffic jam assist
- Partially to fully automated driving

Connectivity
- Smartphone integration
- Telematics
- Ride sharing services
- Predictive maintenance
- C2X connectivity

Enhanced User Experience
- Infotainment
- Climate control
- Customization
- Augmented reality

“The car is the ultimate mobile device.”
Tim Cook
Overview of the Automotive Market

2017 Sales by Regions

Source: Prisarm, Frost & Sullivan, Yole Developpement, GSMA

ALL CARS

- **2017**: 97.2M
- **2022**: 107.3M
- 2.2% CAGR

HEV/EV

- **2017**: ~2.5M
- **2022**: ~4M
- ~25% CAGR

CONNECTIVITY

- **2025**: 100% cars connected

AUTONOMOUS

- **2045**: More than 70% of all vehicles sold will integrate autonomous capabilities

More than 70% of all vehicles sold will integrate autonomous capabilities

Source: Prisarm, Frost & Sullivan, Yole Developpement, GSMA

Electronics & Imaging
Semiconductor Growth in Automotive

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<th>Year</th>
<th>Car Units</th>
<th>Semi Content</th>
<th>Semi/Car</th>
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<tr>
<td>2016</td>
<td>95.3M</td>
<td>$34B</td>
<td>$357</td>
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<td>2017</td>
<td>97.2M</td>
<td>$39B</td>
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YOY: 2.2% Car Units, 14.7% Semi Content, 12.6% Semi/Car

2022:
- Car Units: 107.3M
- Semi Content: $64.5B
- Semi/Car: $601

CAGR 2017-2022:
- 2.0% Car Units
- 10.6% Semi Content
- 8.3% Semi/Car

Source: IC Insights, Gartner
Main Devices and Growth Drivers

- **Engine control**
- **Driver information systems**
- **ADAS**
- **In vehicle networking**

Source: Gartner, Amkor - 2018
Automotive Applications

Increase in HEV/EV and autonomous driving adoption will continue to transform the automotive landscape.
Enabling Auto Electrification and Electronic Systems

CONNECTED ELECTRIC VEHICLES
Broad Participation Under the Hood, Inside the Car and Around It


ELECTRONICS & IMAGING

TRANSPORTATION AND ADVANCED POLYMERS
Accelerated Lightweight Assembly, Battery Pack Structures & Assembly, Thermal Management Systems, Cable Jacketing, Electric Motors, Connectors, Power Control Unit, Sensors & Solenoids, Cooling Lines

SAFETY AND CONSTRUCTION
Tire Reinforcement, Wheel Wall Protection, Side Mirror Housings, Seat Backs, Door Panels, Charging Station Transformers, Battery Pack Protection, Battery Separator, Starters/Alternators, Traction Motors, Generators, Belts, Hoses & Gaskets, Clutch Linings, Brake Pads
Official China Launch at Import Expo Nov 2019

http://ahead.dupont.com/

AHEAD™

SMART SOLUTIONS FOR VEHICLE ELECTRIFICATION AND AUTONOMY

A collaborative partner for a robust and growing market

The drive toward vehicle electrification, autonomous capabilities and associated infrastructure is creating a highly promising market opportunity.

AHEAD™ (Accelerating Hybrid-Electric Autonomous Driving) is a new initiative made possible through DuPont’s experience and expertise in materials science and electronics that offer clear advantages for vehicle electrification and autonomous vehicle markets.

AHEAD™ will provide innovative solutions for:
- Lightweighting
- Battery pack components and assembly
- Thermal management/safety
- Electric motors
- Powertrain/chassis
- Electrical/electronic applications for improved automation, including driver assists and self-driving capabilities.
AHEAD™ Products Work Together in EV Batteries

**Smart Lubrication Solutions**: Molykote®
- Optimizes friction & wear, free motion of adjustable components and corrosion performance. Reduces squeaks & rattles, vibration and harshness (NVH).

**Cabin Heater Solutions**: Kapton®
- Increase power density of high voltage air and liquid PTC heaters by maximized heat dissipation, lightweight

**F-Motor Slot & Wire Insulation**: Kapton®
- Reduced operating temperatures by improved thermal dissipation, lightweight insulation, high voltage endurance, corona resistance, increased power density

**Thermal Management film**: Temprion™ EIF, Temprion™ OHS/Kapton® RS
- a) Reduced operation temperatures enabling increased power
- b) Provides uniform heating, lightweight, flame barrier

**TC Preform Gap Filler**: Temprion™ PGF
- Conformable Sheet, Contamination free Organic solution, High thermal conductivity, Vibration dampening

**E-Motor Slot & Wire Insulation**: Kapton®
- Reduced operating temperatures by improved thermal dissipation, lightweight insulation, high voltage endurance, corona resistance, increased power density

**Cell Separators**: Nomex®
- X-F F/ Kevlar®
- Propagation protection (fire barriers), Thermal insulation to isolate cells/modules

**Integrated Stator plate**: Vizilon® TP, Vizilon® HTN
- Smaller & Lighter (downsizing potential)

**TP resins for electric applications**: Zytel®, Crastin® PBT, Zytel® HTN
- Flame retardant (V0), halogen free solutions, EMI shielding, downsizing potential, Recyclability

**Arc Protection**: Nomex® Papers/Fabrics/Tapes for arc protection (Electronics/busbars)

**Electrical friendly injectable resin**: Zytel®, Crastin® PBT, Zytel® HTN, Zytel® LCP
- Avoids electrical corrosion and facilitates high voltage resistance, downsizing potential

**Cable jacketing & insulations**: Vamac® AE M, Hytrel®
- Halogen Free Flame Retardant (HFFR), low smoke generating, meets high temperature, high voltage demands

**Materials for extruded coolant pipes**: Zytel® LC
- Enables cost competitive mono or bi layer extrusion, lightweight, assembly friendly

**Mechanical Battery pack shield**: Zytel®
- Penetration resistance, vibration dampening (NVH), Lightweight

**Battery pack housing**: Zytel®
- Lightweight, recyclability, EMI shielding enabled

**Sealant or Adhesive**: BET ASEAL™, BETAFORCE™
- Battery pack sealing & assembly; electrical conductive (EMI), dielectrical, structural, primers to plastics

**Dispensable TC Gap Filler**: BET ASEAL™ GF 2.0-TC
- High thermal conductivity, vibration dampening, low thermal resistance and enhanced elongation

**Sealant or Adhesive**: BETAFORCE™, BETAWAVE™, BETASEAL™
- Battery pack, sealing & assembly; electrical conductive (EMI), dielectrical, structural, primers to plastics

**Thermal Conductive Adhesive**: BETAFORCE™ TC
- Thermal Conductive solution, Heat cure accelerate able, high elongation, vibration inhibitor

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Lighter, higher range, cost effective, longer lasting
Increased Functionality Enabled by 3D Packaging/SiP

- Chip area $\uparrow$
- Cost $\uparrow$
- Time to Market $\uparrow$

- $\downarrow$
- Cost

- Performance $\uparrow$
- Size $\downarrow$
- Time to Market $\downarrow$

- Flexibility $\uparrow$
- Efficiency $\uparrow$

- Integration
- Power
- Thermal
- Reliability
- Bio-compatibility
- Storage
- Size
- Cost

- FEOL
- BEOL

- System Integration

- 3D Packaging/SiP

Electronics & Imaging
SiP Adoption Increases across Several Markets and Applications

**Logic & Memory**
- High speed, high I/Os for CPU, ASIC, GPU

**RF/FEM:**
- Power amplifiers
- Switches, Filters, Duplexers
- Antenna modules

**Wireless Connectivity**
- Bluetooth
- Wifi
- SSD cards
- Plug-in wireless

**Power Management**
- Power modules
- Embedded passives
- Controllers

**Sensing Modules**
- MEMS integrated with ASICs
- Combo systems/fusion

**MEMS Modules**
- MEMS integrated with ASICs
- Combo systems/fusion

**Major Benefits**
- Smaller form factor
- Higher performance
- Faster time-to-market
- Lower cost
- High added value
- Increased flexibility

**Markets & Applications**
- Mobile
- IoT & Wearables
- Automotive
- Healthcare
- HPC / Data Centers
- Aerospace & Defense
Main Trends for Automotive Packaging

- **Higher performance & increased function**
  - Faster speeds
  - Higher performance processors
  - Higher bandwidth and IOs (esp. to process optical, radar and lidar data)
  - Higher power density
  - Increased function density
  - Higher frequency
  - Lower parasitics
  - Higher quality
  - Lower cost

- **Packaging Solutions**
  - Higher integration
  - Increase use of Advanced Packaging
  - Heterogeneous integration
  - Advanced heat transfer solutions
  - Advanced stress isolation

Source: Amkor 2017
Technology Evolution: Si, Advanced Packaging & PCB
Automotive Packaging

Traditional IC Packaging

- **Wirebond Packaging**: With enhanced material sets
- **Reliability**: Stringent requirements
- **Ecosystem**: Mostly vertically integrated suppliers

What is changing?

- Analog
- Power
- Dual LF
- MLF®
- Sensors
- Overmolded
- Exposed Die
- Cavity

Accelerated adoption of Advanced Packaging!

Source: Amkor 2017
PCB and Material Trends for Automotive

- PCB designs typically are mainly 4-6L MLB => HDI and Flex are growing for Infotainment applications. Flex substrates are attractive as replacements for conventional wiring harness apps
- ADAS: drives the need for monitoring systems (radar, ultrasonic, cameras), high speed and high frequency applications (e.g., low Dk, Df dielectric materials)
- Power Management: thick copper, high temperature chips (SiC based)
- Powertrain (engine and gearbox): multilayer substrates for high temperature environment
- Thermal Management will continue to be very critical

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<td>ADAS, driver assist, lane keeping, adaptive cruise, en route to Level 5</td>
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<td>Connected Car</td>
<td>Mobility/Vehicle management; Entertainment; Navigation, etc.</td>
</tr>
<tr>
<td>Infotainment Interfaces</td>
<td>Smart HMI including speech / audio / gesture input; Device interface (Apple/Google/other systems)</td>
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<tr>
<td>Energy Efficiency</td>
<td>Engine / power management systems; HEV / EV / Fuel Cell Regenerative braking, light weighting</td>
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<td>High Current</td>
<td>Need copper-heavy products</td>
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<tr>
<td>Heat Management</td>
<td>Heatsinks and thermal management solutions</td>
</tr>
<tr>
<td>High Frequency</td>
<td>RF - High performance materials</td>
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<tr>
<td>HDI Capability</td>
<td>Need for HDI is increased, especially for Infotainment systems</td>
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<tr>
<td>Flexible PCBs</td>
<td>Flex and Rigid Flex for lightweighting, wiring harness</td>
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DuPont Electronic Materials for Automotive

IC & Component Materials
- CMP pads/slurry
- Cleaners
- Photoresist
- Advanced coatings
- Interconnects, damascene plating
- Connectors/passives metallization

Packaging & Module Materials
- Dielectrics
- Thermal adhesives and fillers
- Interconnects, plating chemistries (bumping, Cu pillars, TSV, RDL)
- Polymers (liquid, dry films)
- Final finishes
- Ag paste

PCB & Substrate Materials
- Interconnects: E-less & electrolytic plating (THV, MSAP, SAP, RDL, Cu Pillar, ENIPIG, etc.)
- Lead-frame plating
- Surface finishing
- Dry film
- Laminates
- Ceramic substrates
- Flexible circuits, polymeric and thermal materials

Other Materials:
- Display materials
- OLED materials
- Quantum dots
- High performance plating on plastics
- In-mold electronics
- Light weight materials
**PCB & IC Substrate: Metallization, Laminates & Industrial Films**

**Flex/Rigid-Flex Circuit Laminates & Adhesive**
Material used as a foundation of circuit board.

**Dry Film Photoresists**
Materials to form imaging on various metallic surfaces.

**Electroless Copper**
Materials to produce an initial metallization layer onto which thicker electrolytic copper is subsequently deposited.

**Dry Film Soldermask**
Materials used to provide environment protection to the circuit board.

**Final Finish**
Materials used to apply solderable or wire bondable coatings to components attachment pads.

**Electrolytic Copper**
Materials to apply thick metallic coatings to form both through hole and micro via interconnections.

**EDTA-free E-less (V&H) for HDI, MSAP and SAP**

**MSAP/SAP High Distribution Via Fill**

**Nano-organic coating**

**Dry film Photoresists for advanced patterning**

**LTCC Substrates**

**Flex Laminates**

**Polyimide films**

**HSHF & TM films**
Semiconductor Packaging Materials Portfolio

- SnAg-capped Cu Pillars
- RDL Dielectric
- SnAg/Ni/Cu
- Cu TSV
- Huge Pillars
- Cu RDL
- Copper RDL
- Cu Pillars
- SnAg-Capped Cu Pillars
- Low temp In-Capped Cu Pillars
- SnAg Bump
- Chem-amp Bump Photoresist
- Copper TSV
- Liquid Photodielectric
- Dry Film Dielectric
Semiconductor Assembly Materials Portfolio
Thermally Conductive Organic Direct Bond Copper (ODBC)

Technology:
- Use high thermal conductivity Polyimide as a dielectric layer instead of ceramic (Al₂O₃ or AlN)
- A thermally-conductive, coextruded, trilayer composite polyimide film that can be laminated to copper
- Polyimide based substrates can enable
  - Use of thicker copper (high current density)
  - Lightweight and compact design
  - Cost savings

Advantages:
- Cost effective replacement for ceramic based DBC
- High temperature process replaced with lamination at relatively low temperatures
- Temprion™ Organic Direct Bond Copper creates a stress buffer providing much higher reliability to the power module.

No thermomechanical failure after 2000 thermal shock cycles with thick copper lamination (-55 to +200°C)

With the ability of using thicker copper as laminate—thermal resistance of the ODBC can be better than DBC
Electronic Materials Enable the Automotive Industry

**Plating**
- Electrolytic copper
- Electroless copper
- Innerlayer bonding
- Final finishes

**Deposition**
- High performance plating-on-plastics technology

**Polishing**
- CMP Pad / Slurry Cleaners

**Lithography**
- Photoresist
- Adv. coatings

**Polymer Science**
- Dielectrics
- Encapsulants, adhesives

**Battery mgmt.**
- Power IC / Device

**Power Train & Engine Management**
- HV/PHV/EV/FCV

**LED Lighting**
- Body Electronics

**Vehicle Bus Communication**
- Infotainment & Telematics

**Display**
- Display materials
- OLED materials
- Quantum Dots

**Flexible Display**
- Touch Panel
- Capacitor

**Touch Panel**
- Power

**Sensors**
- Sensors
- EMI Shielding

**Thermal mgmt.**
- Thermal mgmt.

**FPC**
- FPC

**Connector**
- Connector

**EMI Shielding**
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**Polymeric materials**
- Polymeric materials

**Thermal materials**
- Thermal materials

**Instrument Clusters**
- Instrument Clusters

**Display**
- Flexible Display

**Polishing**
- CMP Pad / Slurry Cleaners

**Deposition**
- High performance plating-on-plastics technology

**Plating**
- Electrolytic copper
- Electroless copper
- Innerlayer bonding
- Final finishes

**Polishing**
- CMP Pad / Slurry Cleaners

**Deposition**
- High performance plating-on-plastics technology

**Display**
- Display materials
- OLED materials
- Quantum Dots

**Flexible Display**
- Touch Panel
- Capacitor

**Sensors**
- Sensors
- EMI Shielding

**Thermal mgmt.**
- Thermal mgmt.

**FPC**
- FPC

**Connector**
- Connector

**EMI Shielding**
- EMI Shielding

**CMP Pad / Slurry Cleaners**
- CMP Pad / Slurry Cleaners

**High performance plating-on-plastics technology**
- Deposition

**Display materials**
- Display materials

**OLED materials**
- OLED materials

**Quantum Dots**
- Quantum Dots

**Polymeric materials**
- Polymeric materials

**Thermal materials**
- Thermal materials

**Instrument Clusters**
- Instrument Clusters

**Display**
- Flexible Display

**Polishing**
- CMP Pad / Slurry Cleaners
Thank you!

Driving AHEAD™ with Innovative Materials

Nate Brese, Rozalia Beica
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Wide Portfolio of Materials: Dow Chemical, DuPont & Dow Corning

**Electronics & Imaging**
- World’s largest supplier with the broadest set of materials and technologies to solve complex problems for the semiconductor, circuit board, photovoltaic, display and printing industries.
- **Product Examples**
  - Kapton®, Cyrel®,Tedlar®, IKONIC™

**Safety & Construction**
- Global leader in branded products including fibers & foams, aramid papers, non-wovens, solid surfaces, membranes and protective garments serving the worker safety, construction, oil & gas, energy & transportation markets.
- **Product Examples**
  - Tyvek®, Kevlar®, Nomex®, Corian®, Styrofoam, Great Stuff®

**Nutrition & Biosciences**
- Industry leader in bio-based ingredients and a biosciences pioneer serving the food, nutrition, pharma, home and personal care, biofuels and animal nutrition markets with healthier and more sustainable offerings.
- **Product Examples**
  - Danisco®, Howar®, Methocel™, Avicel®, Sorona®, Bio-PDO™, MECS®, BELCO®, STRATCO®, SILVADUR™, KATHON™

**Transportation & Advanced Polymers**
- Industry leader providing high-performance engineering resins, adhesives, lubricants and parts to engineers and designers in the transportation, electronics and medical markets.
- **Product Examples**
  - Zytre®, Hytre®, Kalrez®, Molykote®, Betascale®, Vespel®

**Strong Engagement and Activities in the Automotive Market**