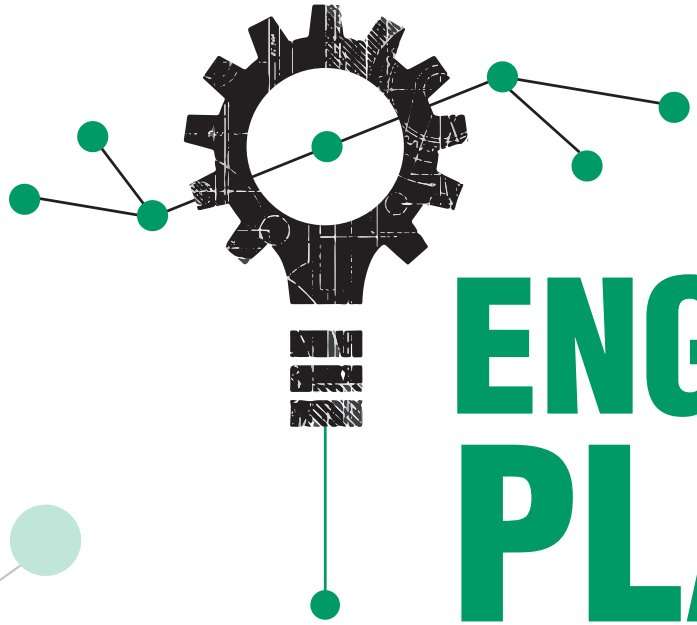


ENGINEERED PLASTICS WORKSHOP

Learn About Thermoplastics | Connect with Experts

2017 **WESTBOROUGH / MASSACHUSETTS**
(BOSTON AREA)

YOUR GLOBAL COMPOUNDER OF
CUSTOM ENGINEERED THERMOPLASTICS

RTP Co.
Imagineering Plastics®

Get Amped Up about Conductive Plastics

Ned Bryant | Senior Product Development Engineer
nbryant@rtpcompany.com
(507) 474-5361

1:30 p.m.

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Get Amped Up about Conductive Plastics

Ned Bryant
Sr. Product Development Engineer

rtpcompany.com • rtp@rtpcompany.com

OVERVIEW

Conductive Classification and Testing

Overview of Conductive Modifiers

- Migratory Anti-stats
- Inherently Dissipative Polymers
- Carbon (Powder, Fiber, Nanotubes)

More Specialized Technology

- EMI Shielding
- Thermal Conductivity

Wrap Up and Questions

WHAT IS CONDUCTIVITY?

Conductivity

- Electrical – A material's ability to carry electric current
- Thermal – A material's ability to conduct thermal energy

Resistivity

- How strongly a material opposes the flow of an electric current

CONDUCTIVE CLASSIFICATION

Anti-static

- Cleanliness
- Prevent dirt & dust build up

Static Dissipative

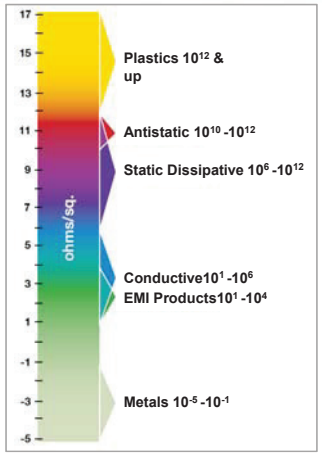
- Protect delicate electronics
- Prevent explosions

Conductive

- Exceptionally sensitive devices
- Grounding electrical circuits

Shielding

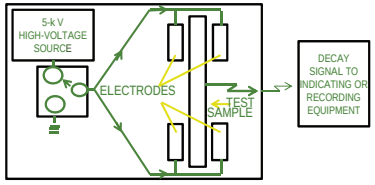
- Provide protection against RFs



STATIC DECAY TESTING

Static Decay Rate

- Measures seconds to decay
- 5000V to 50V
- 12% relative humidity



Standards/Specifications

- MIL PRF 81705 D
- NFPA 56A
- Numerous others

SURFACE TESTING

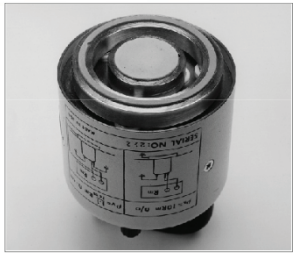
Surface Resistivity (ohms/square)

Surface Resistance (ohm)

Standards/Specifications

- ASTM D257
- ESD STM11.11
- IEC 60079-0
- Numerous others

SURFACE RESISTIVITY TEST



Guarded Ring Electrode

Flat Specimen	Precise Measurement	Units = ohms/square

SURFACE RESISTANCE TEST

Surface <u>Resistance</u> Meter

- Point to point
- Measuring small & critical areas on part
- Units = ohm

SURFACE RESISTANCE TEST

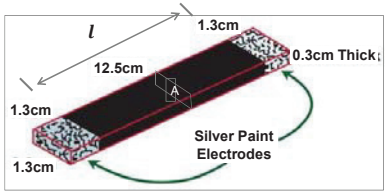
Another Surface Resistance Meter

- Point to point, 5lb weighted probes
- Typically used for flooring applications and large parts
- Units = ohm

VOLUME RESISTIVITY TEST

$$\rho = R\frac{A}{l}$$

ρ = Volume Resistivity
R = Resistance
A = Cross-sectional Area
l = Length



Units = ohm-cm
ASTM D-257

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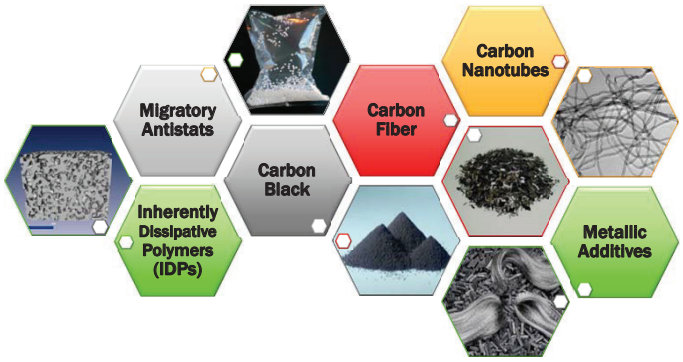
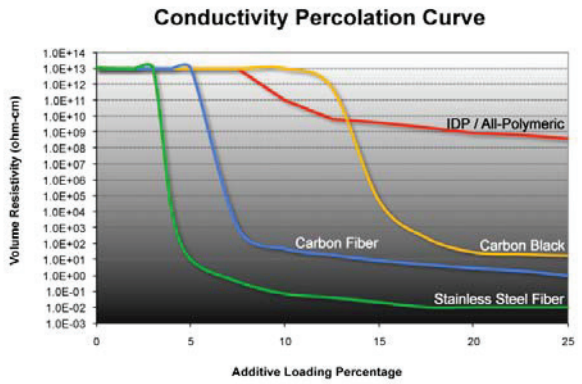
- EMI Shielding
- Thermal Conductivity

Wrap Up and Questions

CONDUCTIVE MODIFIERS



PERCOLATION CURVE



MIGRATORY ANTI-STATIC AGENTS

- Migrating surfactant based – not bonded to resin
- Temperature & humidity dependent
  - Best at room temperature & high humidity
- Colorable
- Liquids & semi-solids with low boiling points
- Compatible only with low temp. resins
  - Olefins, Styrenics, PVC
- Economical/commodity materials

INHERENTLY DISSIPATIVE POLYMERS (IDP)

All-polymeric, based on IDP

- Typically consist of PE oxide
- Other block dictates compatibility
- Forms a co-continuous morphology with the base resin

Over 20 different resin systems

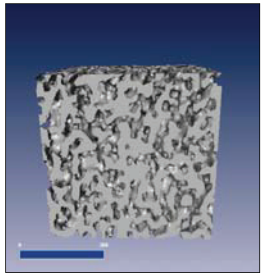
- Limited process temps (< 520 ºF)

Surface resistivity

- Standard: 10^{10} to 10^{11} ohm/sq
- PLUS: 10^{8} to 10^{9} ohm/sq

Static decay rate

- Standard < 2.0 s
- PLUS < 0.5 s



PermaStat®

PERMASTAT® TECHNOLOGY BENEFITS

- Permanent Protection: Not dependent on migration, RH or temperature
- Clean Technology: Non-sloughing, FDA, biocompatible grades available
- Transparent grades available and fully colorable
- Base resin properties retained
- PermaStat PLUS® can meet ATEX requirements

TYPICAL APPLICATIONS

Reticle Boxes
ABS, PMMA

Inhalers
ABS, PP, PMMA

ATEX IBC
PE

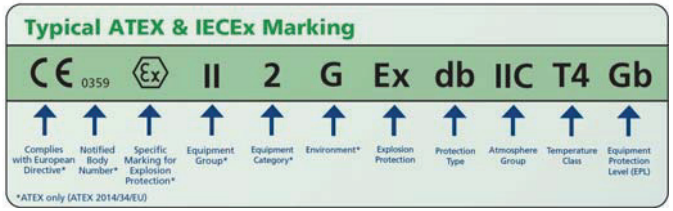
WHAT IS ATEX?

ATMOSPHERE EXPLOSIVE

- Potentially explosive environments

Began as a European Directive

- Standardize compliance procedure
- Now seen in U.S. and other countries (IECEx)



ATEX TESTING

Actual requirements defined by customer

All tests are on actual parts (Article Testing)

Tests typically include:

- Surface Resistance (almost always included)
- Relative Thermal Index (RTI)
- Chemical Resistance
- Impact (Low temperature)
- Ultra Violet (UV)
- High Humidity Aging Testing
- Flame Retardant (FR)

Need to fully identify all requirements for proper material selection

ATEX SURFACE RESISTANCE

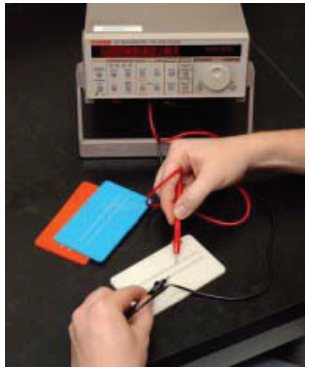
Specific test

- Isolation resistance <1 Gohm at 50% RH
- Tested at 500 V

Different from the standard surface resistance or resistivity widely used in the industry

- IEC 60093
- ASTM D 257
- ESD STM11.11

No real correlation



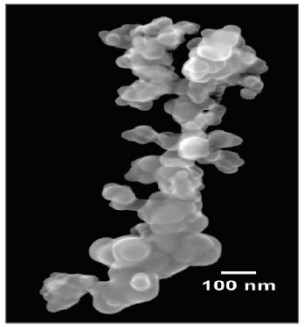
ATEX MARKETS

- **Mining**
- **Personal protective equipment**
- **Food, chemicals, and paint industries**
- **Hand-held equipment**
- **Industrial equipment**
  (pneumatic, hydraulic, venting systems, pumps)

CONDUCTIVE CARBON BLACK

Characterized by:

- Structure
- Size of particles
- Porosity
- Surface Chemistry

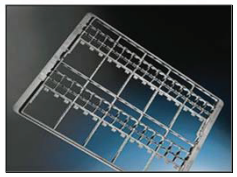


CONDUCTIVE CARBON BLACK

- Permanent
- Black color only
- Sloughing / Marking / Crayoning
- Economical
- Dissipative or conductive

- SR 10^3 to 10^9 ohm/sq.
- VR 10^0 to 10^6 ohm-cm

CARBON BLACK APPLICATIONS



Electronic device trays
PP, PS, PC

Pipette tips
PP

Storage bins & totes
PP

Fuel filler tubes
PE

CARBON FIBER

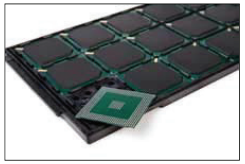
- Non-sloughing
- Colorable
- Anisotropic shrinkage
- Reinforcing
- Dissipative or Conductive
  - SR 10^2 to 10^6 ohm/sq
  - VR 10^{-1} to 10^4 ohm-cm

Chopped Fiber
(6 mm long "bundles")

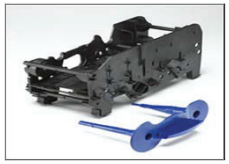
Milled Fiber

CARBON FIBER APPLICATIONS

Full Line components
PPA, Nylon, Acetal



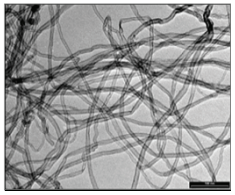
Chip transport/Storage trays
PC, PEI, PES

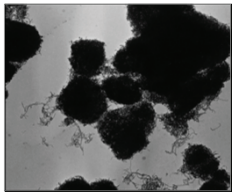


Card printer chassis
PC

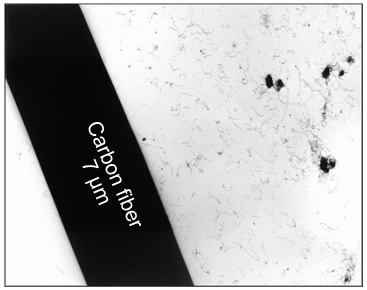
CARBON NANOTUBES (CNT)

- > 90% graphite
- Hollow
- 10 nanometer diameter
- High L/D ratio





CNT IS NANOTECHNOLOGY



A carbon fiber surrounded by CNTs

PRIMARY BENEFITS OF CNTS

Uniform Conductivity – Prevent hot spots

Effective at low loadings – Cleaner product

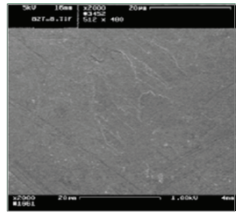
Isotropic Properties – Behaves like neat resin

Ability to use regrind – Maintains conductivity

ELECTRICAL CONDUCTIVITY

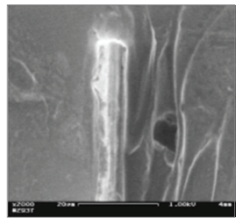
SEM (2000x) of typical CNT compound

- Smooth surface finish
- Uniform shading is a direct result of uniform electrical conductivity



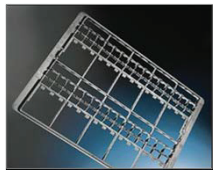
SEM (2000x) of typical CF compound

- Rough surface finish
- White shading indicates a point of high conductivity - "Hot Spot"
- Possible conductive particle generation



ELECTRONICS INDUSTRY APPLICATIONS

- Hard disc drive (HDD) handling components
- Silicon wafer handling components
- Semiconductor chip trays
- ESD shipping trays



Trays

Wafer Caddy

HDD

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More Specialized Technology

- **EMI Shielding**
- Thermal Conductivity

Wrap Up and Questions

INTRODUCTION TO EMI SHIELDING

Electro**M**agnetic **I**nterference = EMI

Emitted from a source *or* Received by a device

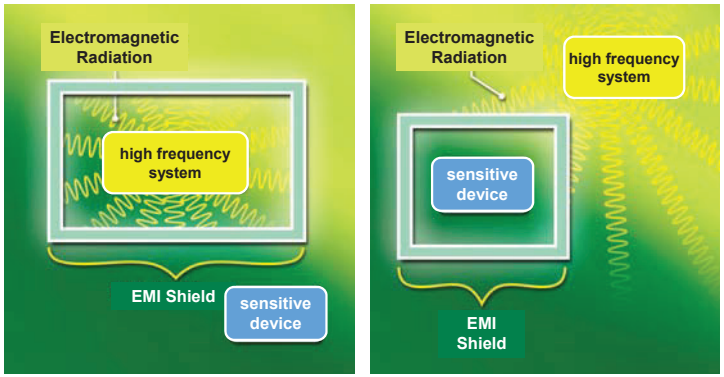
Typical frequency range of 1 kHz to 10 GHz

Faraday Cage Principle, provide "Immunity"

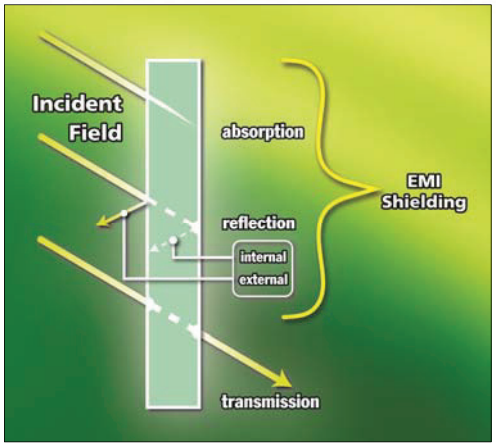
Microwave Oven: 2.45 GHz (122 mm)

EMI IN ACTION

EMI shields protect devices from high frequency sources



EMI IN ACTION



EMI SHIELDING FILLERS

Electrically Conductive modifiers:

- Carbon Black (CB)
- Carbon Fiber (CF)
- Graphite
- **Stainless Steel Fiber (SSF)**
- **Nickel Coated CF (NCCF)**
- Other metallic additives

KEY ADDITIVE COMPARISON

SSF

- Minimal affect on neat resin properties
- **Neat resin shrinkage**
- Good shielding
- Cost effective
- Colorable

NCCF

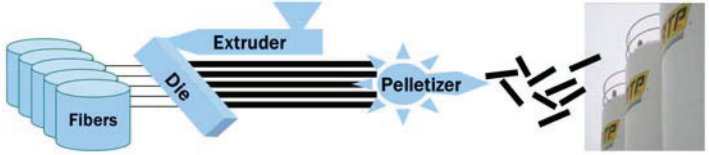
- Properties similar to carbon fiber compounds
- High shielding performance
- Higher cost
- Less colorable

WHAT TYPE OF SSF?

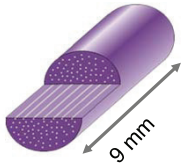
Stainless Steel Fiber

- 8 µm Diameter
- 304 Tool Steel
- Very Flexible

THE LONG FIBER PROCESS

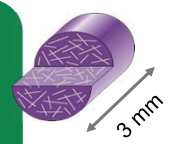


CUBE BLENDS



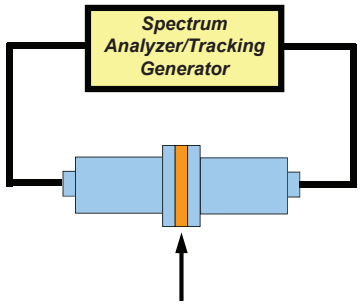
Cube blend

- Physical blend of resin with conductive modifier
- Necessary to retain aspect ratio (fiber length)
- Evenly dispersed during injection molding
- SSF loading up to 20%



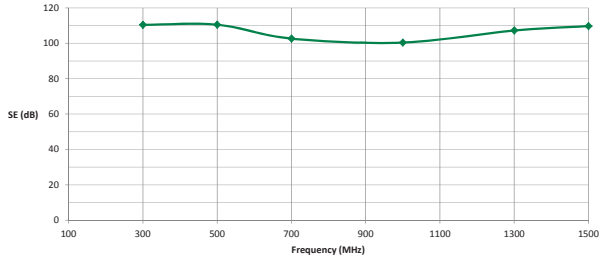
COAXIAL TRANSMISSION LINE TEST

- ASTM D4935
- Direct measurement method
- Relative ranking of materials
- Frequency range of 300MHz to 1.5 GHz
- Fast & Repeatable
- Flat test specimen – min. 6" diameter
- Units = Decibels of SE



TEST RESULTS

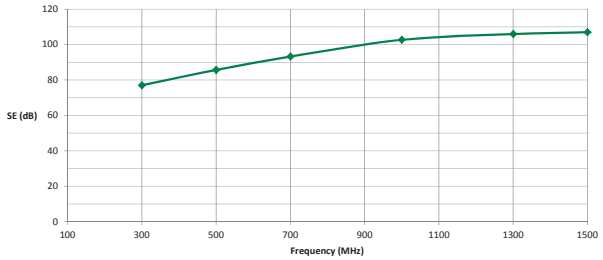
2 mm Aluminum Plate



This represents the Maximum Capability of the test equipment.

TEST RESULTS

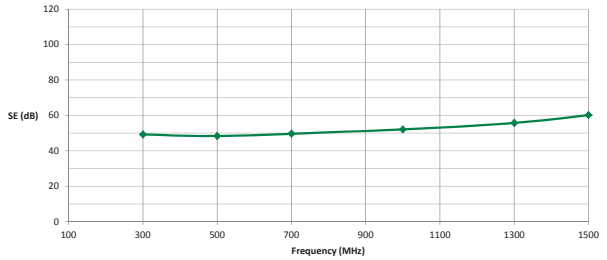
EMI 1062, 3 mm



15% SSF

TEST RESULTS

RTP 1099 X 134945 A, 2 mm



This is a combined technology with conductive fillers and SSF to increase the low frequency SE.

EMI SHIELDING METHODS

- Actual metal housing
- Metallic paint/metal coatings
  - Traditional TV Cabinets
- Metal foil/screen
  - Microwave Oven
- Polymer compound
  - Increases design freedom, part consolidation
  - Eliminates secondary operations & reduces part cost

METAL OR PLASTIC

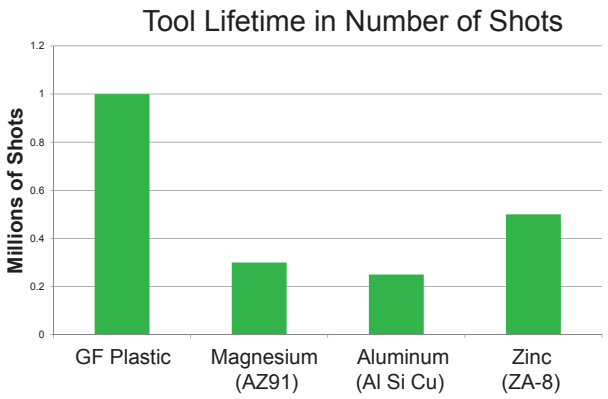
Metal

- High Thermal Conductivity
- High Electrical Conductivity (EMI Shielding)
- Very High Stiffness
- Very Low Creep
- Low CLTE
- High Strengths at High Temperatures
- Narrow Tolerances are Realistic

Plastic

- No Corrosion
- Lower Density
- Design Freedom (Integration of Functions)
- **High Tool Life Time**
- Good Chemical Resistance
- Acoustic Dampening
- Consolidation of Parts

TOOL LIFETIME IN SHOTS



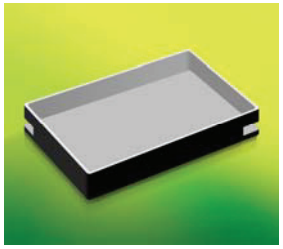
CONTROLLING EMI

EMI Shielding is a function of 4 variables:

- **Conductivity of the material**
- Thickness of the material
- Frequency of the interference
- Distance between the source of the interference and the shield

ELIMINATE CONDUCTIVE PAINT

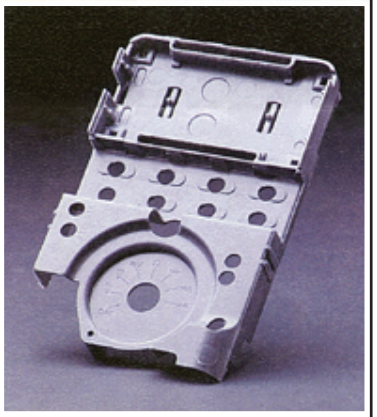
- Review of Conductive Paint:
  - Durability (flaking and scratching)
  - Potential thin spots in coating
  - Yield fallout from masking operation
  - Environmental considerations
  - Additional process
  - Additional supplier
  - Additional $$$



METAL REPLACEMENT

EMI 300 Series (PC):

- UL Listed (V-0 @ 1.5 mm)
- SE 30-70 dB
- GF from 0% - 20%
- Economical alternative to metal or coated plastics



COMBINING EMI & THERMAL CONDUCTIVITY (TC)

- SSF is a poor thermal conductor
- Thermal fillers can provide some EMI shielding
- Custom formulations can balance design requirements

RTP Formulation	SE @ 2 mm (300 MHz – 1.5 GHz)	TC (Through-plane)	TC (In-plane)
EMI 2562	60 – 85 dB	0.3 W/mK	---
299X124222C	30 – 55 dB	3.4 W/mK	25 W/mK
299X124222D	32 – 38 dB	3.1 W/mK	19 W/mK
299X124222E	40 – 60 dB	5.3 W/mK	32 W/mK
299X124223B	45 – 55 dB	1.4 W/mK	4.1 W/mK

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- **Thermal Conductivity (TC)**

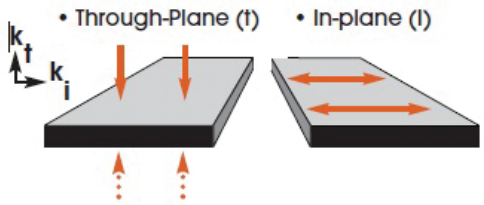
Wrap Up and Questions

TC ADVANTAGES

Property	Unfilled Plastics	TC Compounds	Aluminum
TC	0.1 – 0.2 W/m-K	1 – 35 W/m-K	150 – 250 W/m-K
Isotropic TC	No	No	Yes
Manufacturing processes	Injection molding, extrusion	Injection molding, extrusion	Casting, machining, extrusion
Design freedom	Unlimited	Unlimited	Limited by mfg processes
Weight (g/cc)	0.9 – 1.1	1.5 – 1.8	2.7
Shipping cost	reduced	reduced	standard
Electrical isolation	Yes	Possible	Not possible
Color	Unlimited	White, Gray & Colors	Gray only

TC DESIGN - ANISOTROPY IN PLASTICS

- **Through Plane**
  - Measured perpendicular to the flow of material
  - "Worst case scenario" for TC
- **In Plane**
  - Measured parallel to the flow of material
  - Influenced by fillers with high aspect ratios
  - Important for spreading and directing thermal energy



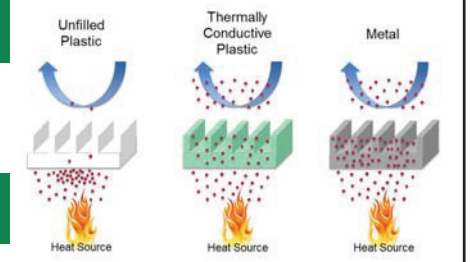
TC DESIGN – CONVECTION CONSTRAINT

Convection Limited

- The high TC of metal is typically not necessary
- Limited by convection to the environment

More Surface Area

- Ribs, fins and pins maximize convection
- Reduce the bottleneck in thermal transfer



Unfilled Plastic	Thermally Conductive Plastic	Metal
Energy is not conducted through the plastic part	Energy is conducted through the plastic part	Energy is conducted through the metal part
Energy not available for convective heat transfer	Energy is available for convective heat transfer	Energy is available for convective heat transfer
Conduction Limited	Balanced System	Convection Limited

TC DESIGN – RADIANT HEAT TRANSFER

- Heat Transfer is a combination of:
  - Conduction, Convection, & Radiation
- Metals possess poor radiant transfer properties
- TC plastics possess excellent radiant properties
- This has real advantages, especially in doors or behind dashboards (places with low airflow rates)
- Al can be anodized to increase radiant heat transfer, but this is an additional process and cost to the system

TC FILLER OPTIONS

Electrically Conductive	Electrically Isolating
• Utilizes graphite and metallic fillers • Allows for higher thermal conductivity at a lower cost • Provides no dielectric strength to assembly • Typically produces black colored compounds • Thermal conductivity: – *Through-plane k = 1.0 to 8.0 W/mK* – *In-plane k = 2.0 to 35.0 W/mK*	• Utilizes ceramic fillers • Compromises some thermal conductivity to maintain electrical isolation • Dielectric strength allows for lower cost, more creative LED designs • Good choice when white color is desired • Thermal conductivity: – *Through-plane k = 0.5 to 2.5 W/mK* – *In-plane k = 1.0 to 10.0 W/mK*

TC VALUE

Why convert from metal?

- Highly complex geometries
- Increase surface area
- Weight reduction
- Simplified manufacturing
- Corrosion resistance
- Increased design freedom
- **Cost Reduction**

CONDUCTIVE MODIFIERS: PROS AND CONS

Technology	Pros	Cons
Migratory Antistats	• Economical	• Non-permanent • Process temperature limited • Humidity dependent
Inherently Dissipative Polymer PermaStat®	• Permanent • Transparent availability • Colorable • No loss of mechanical properties	• Limited to dissipative range • Process temperature limited
Carbon Black	• Economical • Dissipative or conductive • Resists Tribocharging	• Sloughing • Black only • Lower impact strength
Carbon Fiber	• Dissipative or conductive • Reinforcing • Non-sloughing	• Anisotropy • Poor tribocharging
Carbon Nanotubes	• Dissipative or conductive • Superior tribocharging performance • Minimal effect on mechanical and viscosity • Low Liquid Particle Count (LPC)	• Cost • Black only
Metallic Additives	• EMI/RFI shielding • Highly conductive	• Limited colorability • Higher specific gravity
Ceramic Additives	• Provide Thermal Conductivity • Electrically insulative	• High loadings required • Reduction in physical properties

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Thank You!

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