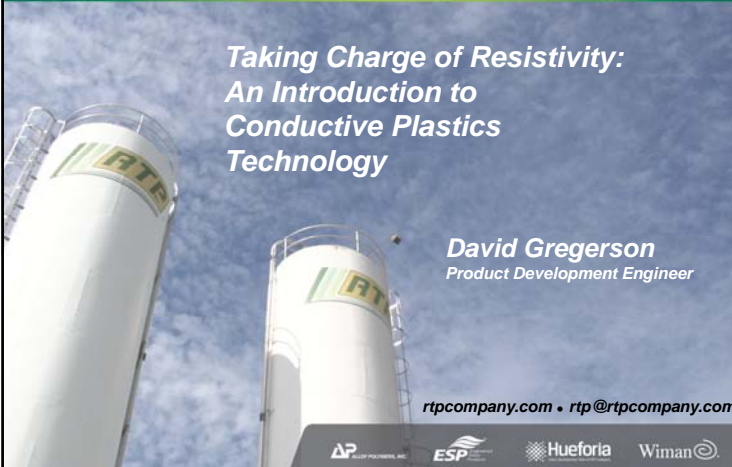


RTP COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Taking Charge of Resistivity: An Introduction to Conductive Plastics Technology

David Gregerson
Product Development Engineer

rtpcompany.com • rtp@rtpcompany.com

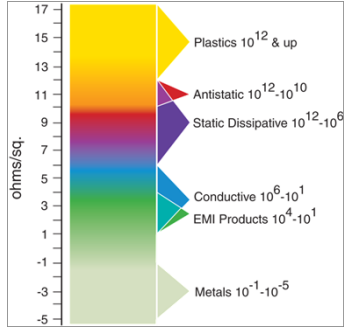


RTP OVERVIEW

- Conductive Classification and Testing
- Overview of Conductive Modifiers
 - Migratory Anti-Stats
 - Inherently Dissipative Polymers
 - Carbon (Powder, Fiber, Nanotubes)
- More Specialized Technologies
 - EMI Shielding
 - Thermal Conductivity
- Wrap Up and Questions

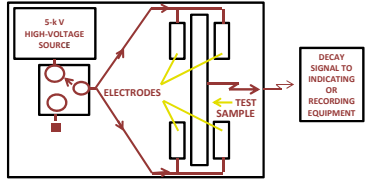

RTP CONDUCTIVE CLASSIFICATION

- Antistatic
 - Cleanliness
 - Prevent Dirt & Dust build up
- Static Dissipative
 - Protect Delicate Electronics
 - Prevent Explosions
- Conductive (Current-Carry Devices)
 - Electrical Contacts
 - Electrical Circuits
- Shielding
 - Provide Protection against RFs



RTP 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





RTP SURFACE TESTING


- Surface Resistivity (ohms/square)
- Surface Resistance (ohm)
- Standards/Specifications
 - ASTM D257
 - ESD STM11.11
 - IEC 60079-0
 - Numerous others

RTP SURFACE RESISTIVITY TEST

- Small Samples
- Irregular Part Shapes
- In-Field Test
- Units = ohms/square



Voyager SRM-110



RTP SURFACE RESISTIVITY TEST



Guarded Ring Electrode

- Flat Specimen
- Precise Measurement
- Units = ohms/square

RTP SURFACE RESISTANCE TEST

Surface Resistance Meter

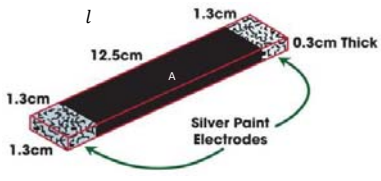
- Point to Point
- Measuring small & critical areas on part
- Units = ohm




RTP 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

RTP OVERVIEW

Overview of Conductive Modifiers

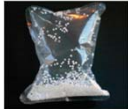
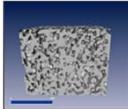


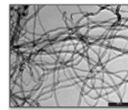

- Migratory Anti-Stats
- Inherently Dissipative Polymers
- Carbon (Powder, Fiber, Nanotubes)

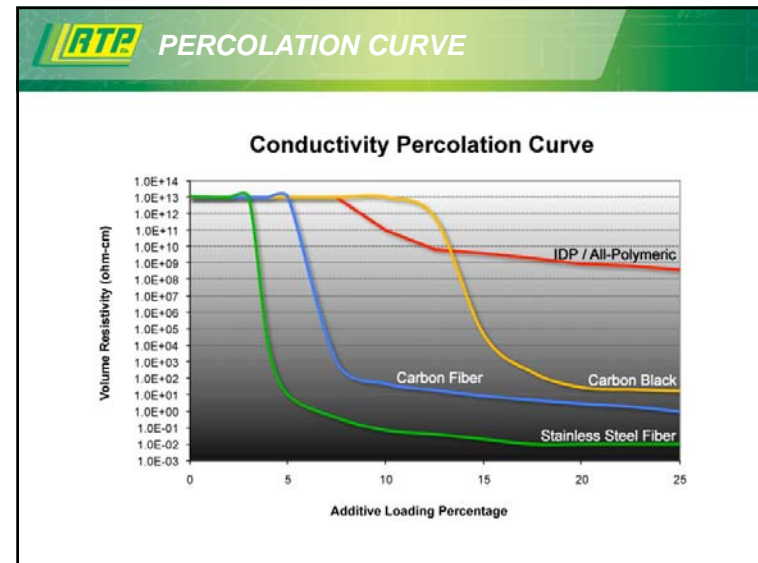
More Specialized Technologies

- EMI Shielding
- Thermal Conductivity

Wrap Up and Questions


RTP CONDUCTIVE MODIFIERS

Migratory Antistats		Inherently Dissipative Polymers (IDPs)	
Carbon Black		Carbon Fiber	
Carbon Nanotubes		Metallic Additives	



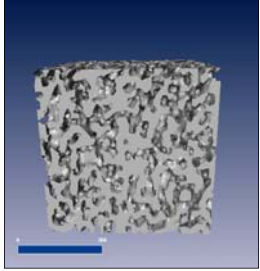
MIGRATORY ANTI-STATIC AGENTS

- 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 °F)
- Surface resistivity
 - Standard: 10^{10} to 10^{12} 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 ESD protection – not dependent on migration, humidity or temperature
- Clean Technology – non sloughing with FDA and 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



Gas Cap

- POM



ATEX IBC

- PE

WHAT IS ATEX?

ATMOSPHERE EXPLOSIVE

- Potentially explosive environments

Began as a European Directive

- Standardize compliance procedure
- Now seen in US and other countries (IECEX)



ATEX TESTING

Actual requirements defined by customer

All tests are on actual parts

Tests could 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% R.H.
 - Tested at 500 V
- Different from the standard surface resistance or resistivity widely used in the plastic industry
 - IEC 60093
 - ASTM D 257
 - ESD STM11.11
- No real correlation



ATEX MARKETS

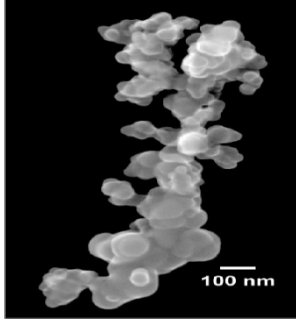
- Mining
- Personal protective equipment
- Food, chemicals, and paint industries
- Hand-held equipment
- Industrial equipment (pneumatic, hydraulic, venting systems, pumps)



RTP CONDUCTIVE CARBON BLACK


Characterized by:

- Structure
- Size of particles
- Porosity
- Surface Chemistry



RTP 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



RTP CARBON BLACK APPLICATIONS



Electronic device trays
PP, PS, PC



Pipette tips - PP




Storage bins
& totes - PP




Fuel filler tubes - PE

RTP CARBON / GRAPHITE 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 –
¼" long "bundles"



Milled Fiber –
pulverized

RTP CARBON FIBER APPLICATIONS



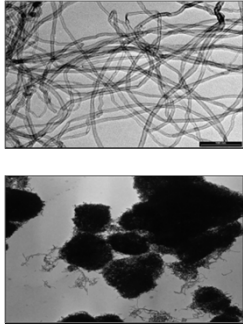
Full Line components
PPA, Nylon, Acetal

Chip transport/Storage trays
PC, PSUL, PES

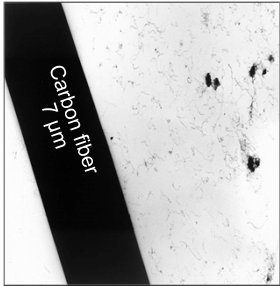
Card printer chassis
PC

RTP CARBON NANOTUBES (CNT)

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



RTP CNT SIZE DIFFERENCE



Carbon fiber
7 μm

A carbon fiber surrounded by CNTs

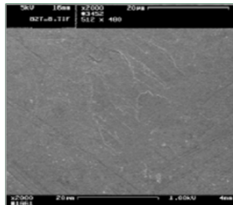
RTP PRIMARY BENEFITS OF CNTS

- Uniform electrical conductivity - prevent hot spots and protect sensitive electronics
- Effective at low loadings – clean product with low SG and good surface finish
- Isotropic Properties – non reinforcing, behaves like neat resin
- Ability to use regrind – maintains conductivity with additional processing

RTP ELECTRICAL CONDUCTIVITY

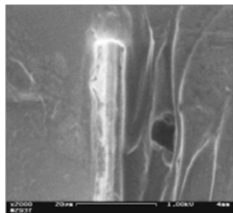
SEM (2000x) of typical CNT compound

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

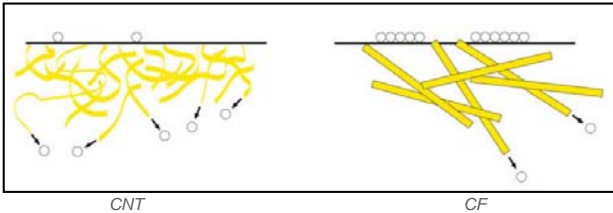


SEM (2000x) of typical CF compound

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



RTP HOT SPOTS



Fewer Hot Spots

Lower Voltage Retention

Reduced Tribocharging

RTP ELECTRONICS INDUSTRY APPLICATIONS

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



Trays



Wafer Caddy



HDD

RTP OVERVIEW

More Specialized Technologies

- EMI Shielding
- Thermal Conductivity

Wrap Up and Questions

RTP EMI SHIELDING

ElectroMagnetic Interference = EMI

Emitted from a source or Received by a device

Frequency range of 1 kHz to 10 GHz

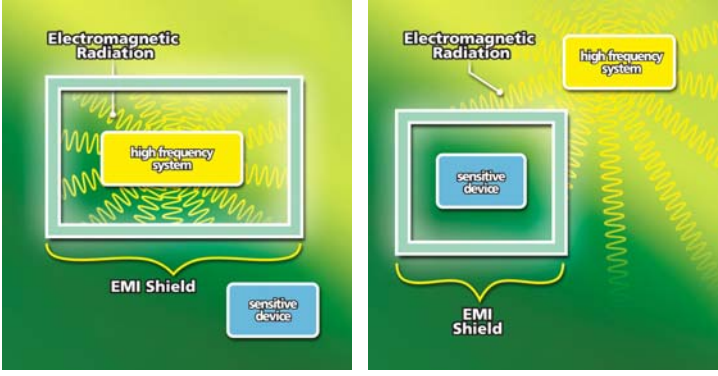
Faraday Cage Principle:

- Barrier that reflects or conducts signals to ground

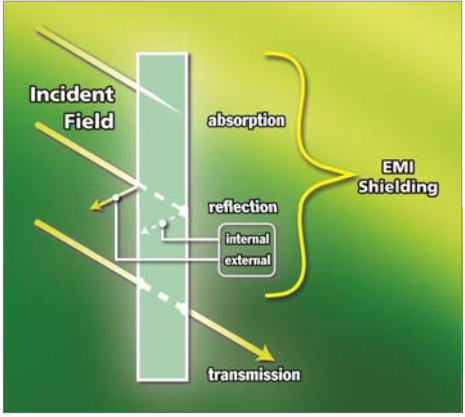
Shielding provides “Immunity”

RTP EMI IN ACTION

EMI shields protect sensitive devices



RTP EMI IN ACTION




RTP EMI SHIELDING FILLERS

Electrically Conductive modifiers:


- Carbon Powder
- Carbon fiber
- Graphite
- **Stainless steel fiber**
- **Nickel-coated carbon fiber**
- Other metallic additives

ADDITIVE COMPARISON



Stainless Steel Fiber

- Non-Reinforcing
- Equivalent shrinkage to neat resin
- Moderate shielding performance
- Colorable

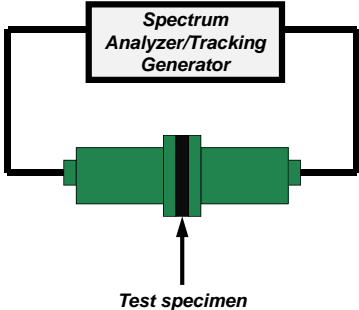



Nickel-Coated Carbon Fiber

- Reinforcing
- High shielding performance
- Higher cost
- Less colorable

COAXIAL TRANSMISSION LINE TEST

- ASTM D 4935
- Direct Measurement on Flat Specimens
- Fast and Repeatable
- Relative Ranking
- Frequency range of 30 MHz to 1.5 GHz
- Units = Decibels of SE





REVIEW OF SHIELDING OPTIONS

 <p>EMI Compound</p> <ul style="list-style-type: none"> • VR is key parameter • SR is misleading • SE dependent on filler loading and wall thickness • Easily Grounded 	 <p>Conductive Coated Plastic</p> <ul style="list-style-type: none"> • SR key parameter • Other surfaces insulative • SE depends on coating Conductivity & Thickness • Care in grounding required 	 <p>Metal</p> <ul style="list-style-type: none"> • Uniform Conductivity • SR easily measured • Easily grounded
--	---	---

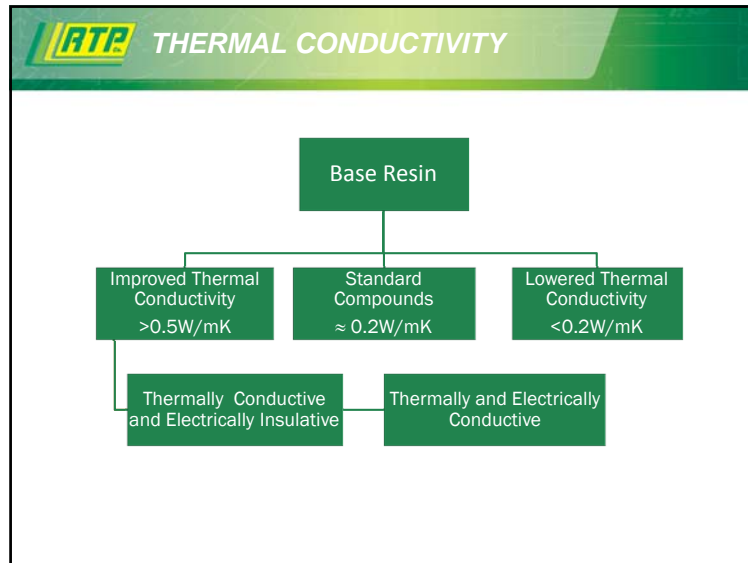
EMI APPLICATIONS



Shielding gasket
TPO/SS



Motor Housing
PC/NCCF



RTP THERMALLY CONDUCTIVE ADDITIVES

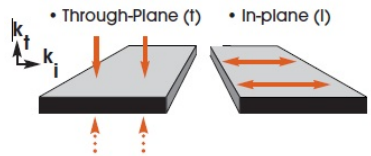
Electrically Conductive

- Carbon based
- In Plane up to 30 W/mK
- Through Plane up to 6 W/mK
- Color limited to Black/Grey

Electrically Insulative

- Ceramic based
- In Plane up to 10 W/mK
- Through plane up to 1.5 W/mK
- Colorable

RTP ADDITIVE ORIENTATION



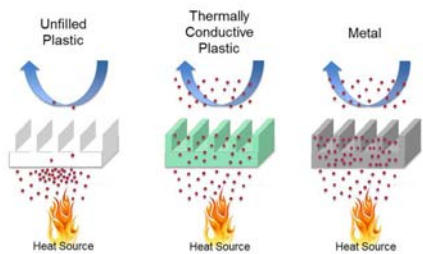
Thermal Conductivity is measured in the direction of flow (in plane) and in the direction normal to the plane of flow (through plane)

Alignment of particles during molding leads to higher thermal conductivity in the in-plane direction

RTP METAL REPLACEMENT

Convection Limited Systems

- Higher conductivity of metal often not necessary
- Limited to what can be dissipated to environment



Increase Surface Area

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

RTP BENEFITS

- Much higher thermal conductivity than conventional thermoplastics
- Ease of manufacturing net shapes compared to metals
- Significant weight savings even compared to lightweight Al
- EMI + TCC solutions available for complete metal replacement

RTP THERMALLY CONDUCTIVE APPLICATIONS



Electronics Housing



LED Heatsinks

RTP CONDUCTIVE MODIFIERS: PROS AND CONS

Technology	Pros	Cons
Migratory Antistats	<ul style="list-style-type: none"> Economical 	<ul style="list-style-type: none"> Non-permanent Process temperature limited Humidity dependent
Inherently Dissipative Polymer PermaStat®	<ul style="list-style-type: none"> Permanent Transparent availability Colorable No loss of mechanical properties 	<ul style="list-style-type: none"> Limited to dissipative range Process temperature limited
Carbon Black	<ul style="list-style-type: none"> Economical Dissipative or conductive Resists Tribocharging 	<ul style="list-style-type: none"> Sloughing Black only Lower impact strength
Carbon Fiber	<ul style="list-style-type: none"> Dissipative or conductive Reinforcing Non-sloughing 	<ul style="list-style-type: none"> Anisotropy Poor tribocharging
Carbon Nanotubes	<ul style="list-style-type: none"> Dissipative or conductive Superior tribocharging performance Minimal effect on mechanical and viscosity Low LPC 	<ul style="list-style-type: none"> Cost Black only
Metallic Additives	<ul style="list-style-type: none"> EMI/RFI shielding Highly conductive 	<ul style="list-style-type: none"> Limited colorability Higher specific gravity

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

Thank You!

rtpcompany.com • rtp@rtpcompany.com

