



RTP 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

RTP WHAT IS CONDUCTIVITY?

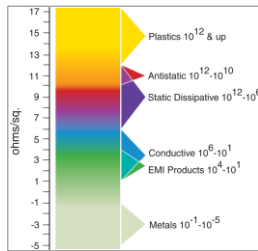
- Conductivity**
 - Electrical
 - Measure of a material's ability to carry an electric current
 - Thermal
 - Measure of a material's ability to conduct/transfer heat
- Resistivity**
 - Measure of how strongly a material opposes the flow of electric current

RTP QUICK REFRESHER ON NOTATION

- How many ways can you write "One Billion Ohms"?
 - 1,000,000,000 Ω
 - $1 \times 10^9 \Omega$
 - 1.0E+9 Ω
 - $1 \times 10^9 \Omega$
 - 1e9 Ω
 - $10^9 \Omega$
 - 1 GΩ

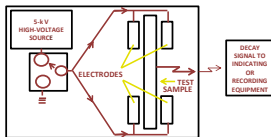
RTP CONDUCTIVE CLASSIFICATION

- 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 SURFACE RESISTANCE TEST

Another Surface Resistance Meter

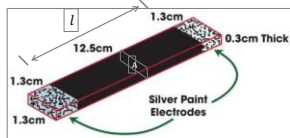
- Point to Point, 5lb weighted probes
- Typically used for flooring applications and large parts
- Units = ohm



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

Conductive Classification and Testing

Overview of Conductive Modifiers

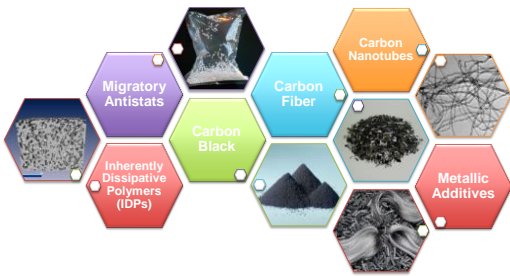
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More Specialized Technologies

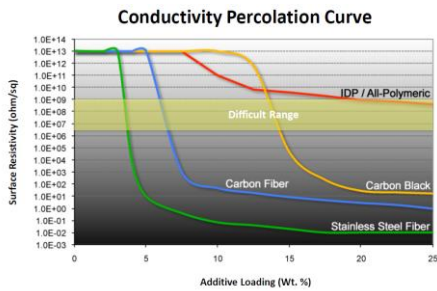
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- Thermal Conductivity

Wrap Up and Questions

RTP CONDUCTIVE MODIFIERS



RTP PERCOLATION CURVE



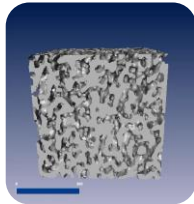
RTP MIGRATORY ANTI-STATIC AGENTS

- 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



RTP 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^{11} ohm/sq
 - PLUS: 10^8 to 10^9 ohm/sq
- Static decay rate**
- Standard < 2.0 s
 - PLUS < 0.5 s



PermaStat®

RTP 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

RTP TYPICAL APPLICATIONS



Reticle Boxes
ABS, PMMA



Inhalers
ABS, PP, PMMA



Gas Cap
POM



ATEX IBC
PE

RTP WHAT IS ATEX?

ATMOSPHERE EXPLOSIVE

- Potentially explosive environments

Began as a European Directive

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

Typical ATEX & IECEx Marking

CE	0359	Ex	II	2	G	Ex	db	IIC	T4	Gb
↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Complies with European Directives*	Notified Body Number*	Specific Marking for Explosion Protection*	Equipment Group*	Equipment Category*	Environment*	Explosion Protection	Protection Type	Atmosphere Group	Temperature Class	Equipment Protection Level (EPL)

*ATEX only (ATEX 2014/54/EU)

RTP 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

RTP ATEX SURFACE RESISTANCE

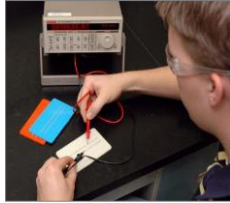
Specific test

- Isolation resistance
- $<10^9$ at 50% R.H.
- $<10^{11}$ at 30% 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



RTP ATEX MARKETS

Mining

Personal protective equipment

Food, chemicals, and paint industries

Hand-held equipment

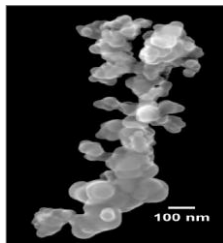
Industrial equipment
(pneumatic, hydraulic, venting systems, pumps)



RTP CONDUCTIVE CARBON BLACK

Characterized by:

- Structure
- Size of particles
- Porosity
- Surface Chemistry

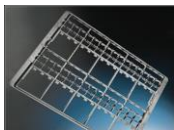


RTP CONDUCTIVE CARBON BLACK

- 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
1/4" long "bundles"

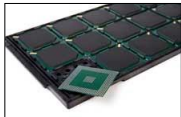


Milled Fiber
pulverized

RTP CARBON FIBER APPLICATIONS



Full Line components
PPA, Nylon, Acetal



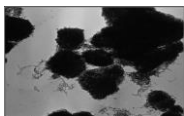
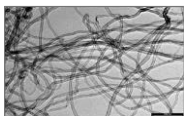
Chip transport/Storage
trays
PC, PSUL, PES



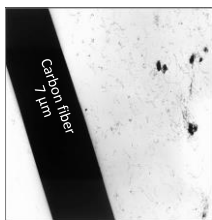
Card printer chassis
PC

RTP CARBON NANOTUBES (CNT)

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



RTP CNT SIZE DIFFERENCE



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

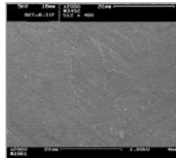
Isotropic Properties – non reinforcing, behaves like neat resin

Ability to use regrind – maintains conductivity with additional processing

RTP ELECTRICAL CONDUCTIVITY

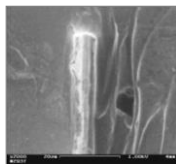
SEM (2000x) of typical CNT compound

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

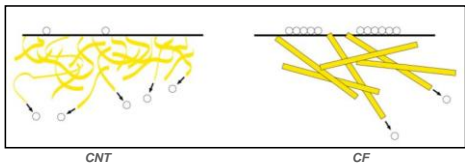


SEM (2000x) of typical CF compound

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



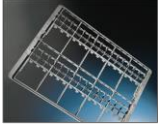
RTP HOT SPOTS



- 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

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RTP EMI SHIELDING

ElectroMagnetic Interference = EMI

Emitted from a source or Received by a device

Frequency range of 1 kHz to 10 GHz

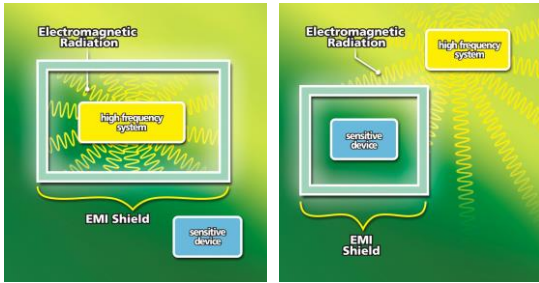
Faraday Cage Principle:

- Barrier that reflects or conducts signals to ground

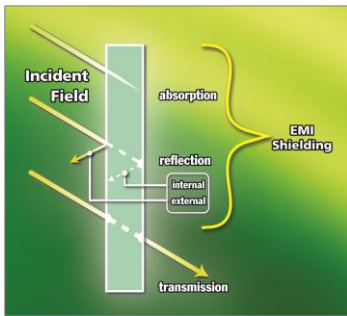
Shielding provides "Immunity"

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

RTP ADDITIVE COMPARISON



Stainless Steel Fiber

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



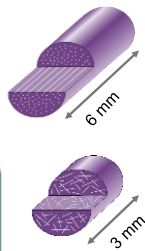
Nickel-Coated Carbon Fiber

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

RTP CUBE BLENDS

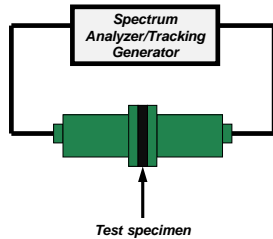
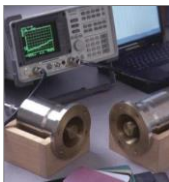


- Cube blend**
- Physical blend of neat/modified resin with conductive modifier
 - Long-fiber stainless steel/nickel coated CF
 - Retain fiber length/aspect ratio
 - Dispersed during injection molding process

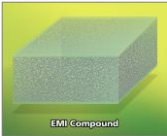


RTP COAXIAL TRANSMISSION LINE TEST

- 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

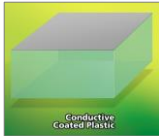


RTP REVIEW OF SHIELDING OPTIONS



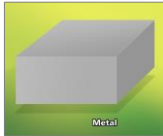
EMI Compound

- VR is key parameter
- SR is misleading
- SE dependent on filler loading and wall thickness
- Easily Grounded



Conductive Coated Plastic

- SR key parameter
- Other surfaces insulative
- SE depends on coating conductivity & thickness
- Care in grounding required
- Can flake or chip off



Metal

- Uniform Conductivity
- SR easily measured
- Easily grounded
- Design limitations

RTP EMI APPLICATIONS



Shielding gasket
TPO/SS



Motor Housing
PC/NCCF

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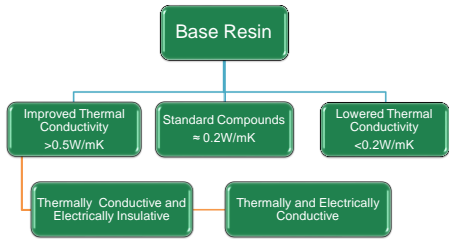
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RTP THERMAL CONDUCTIVITY



RTP THERMALLY CONDUCTIVE ADDITIVES

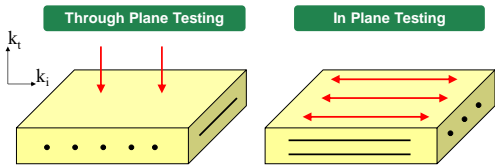
Electrically Conductive

- Carbon fiber
- Milled carbon fiber
- Pitch fiber
- Graphite
- Anything carbon-based

Electrically Insulative

- Ceramics

RTP MEASUREMENT METHODS



Thermal conductivity can be orientation dependent with high aspect ratio fillers

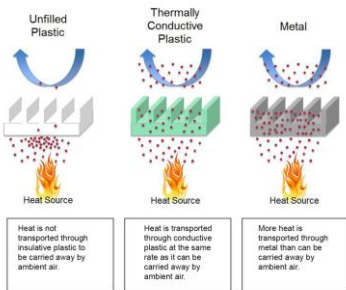
RTP ADVANTAGES

Why convert metal?

- Injection mold complex geometri
- Increase surface area
- Weight reduction
- Simplified manufacturing
- Corrosion resistance
- Improved wear performance
- Cost Reduction
- **Increased Design Freedom**



RTP WHY CONVERT METAL?



In many cases, thermally conductive plastic can perform as well as metal despite having lower thermal conductivity!

RTP DISADVANTAGES

Processing challenges

- Highly filled
- Freeze off in mold

Physical properties

- High specific gravity
- Brittleness

Limited thermal conductivity

