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

Ultraviolet (UV) Resistance for Plastics

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ALLOY POLYMERS, INC. ESP Engineered Sheet Products Hueforia Colour Development Team of RTP Company Wiman

COMPANY PROFILE

RTP Company is an independent, privately owned custom compounder with Global manufacturing and engineering support, Worldwide sales representation and distribution.

Established in 1982

1500+ employees

$500+ million annual sales

PRODUCT DEVELOPMENT/R&D

- **50+ Product Development Engineers worldwide**
- **Regional engineers for local support**
- **Dedicated pilot plants in each region of the world**
  - Product development
  - Process development
  - Customer trials and samples
  - Equipped for easy scale-up to production

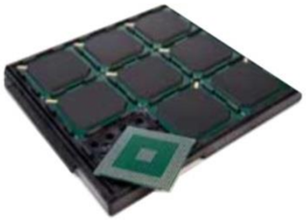
Global Manufacturing

18 Locations

PRODUCT FAMILIES

Compounds formulated to meet performance requirements, from one property to multiple technologies

Color



Conductive

Flame Retardant

Thermoplastic Elastomers

Structural

Wear Resistant

Film - Wiman

Sheet - ESP™

RTP COMPANY COLOR DIVISION

Color virtually all resins

- Engineering resins
- Styrenic resins
- Polyolefin resins

Color in multiple formats

- Masterbatches
- Precolored resins
- Cube blends

Advanced Color Development

- Custom colors
- Multiple light sources
- Regulatory knowledge
  - UL, FDA, USP, RoHS, etc.

MARKETS

Appliances

Automotive

Business & Cash Machines

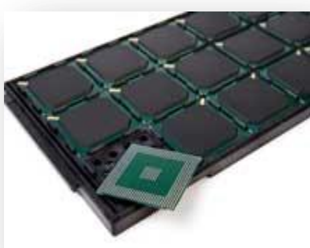
Construction & Agriculture

Consumer

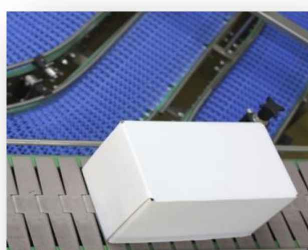
Defense & Aerospace

Energy

Electrical/Electronics



Electronic Packaging & Data Storage



Industrial

Medical

Sports & Leisure

TODAY'S AGENDA

- What is UV and weathering?
- Material choices for improved UV resistance
- Material testing and reporting
- Case studies
- Conclusion and questions

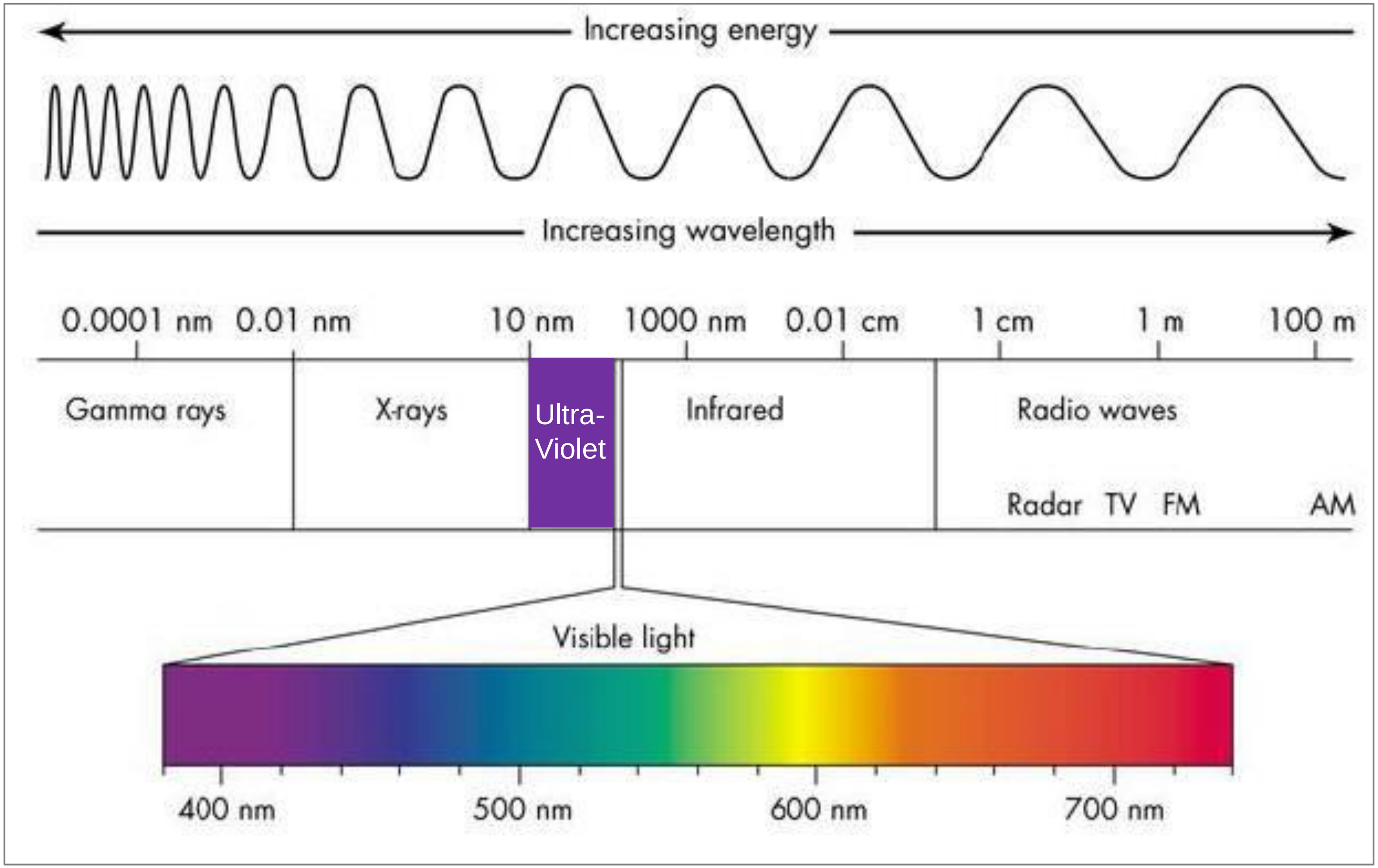
WEATHERING OF PLASTICS

- Weathering is a broad term defining the exposure to all of the elements of nature, but the primary concerns are:
  - Solar radiation
  - Variation in temperature
  - Rain and other forms of precipitation

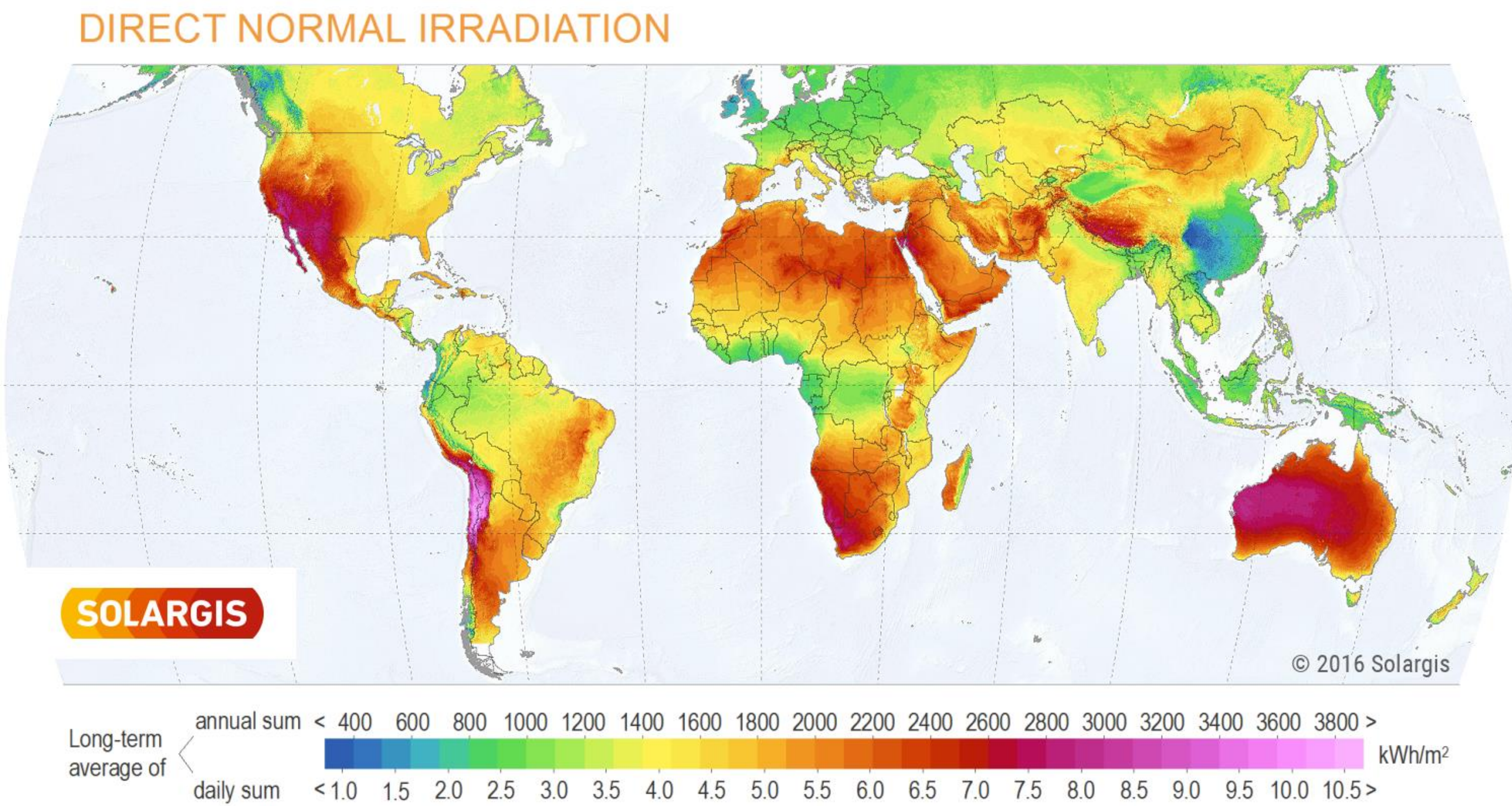
- Over time, exposure to sunlight, and other sources of UV radiation, will degrade all plastics. Performance varies with polymer matrix. Weathering includes the variables of temperature, precipitation, and variation in sunlight intensity.

- Of these three our focus for today’s discussions will center on solar radiation and in particular the Ultraviolet region of the electromagnetic spectrum.

ELECTROMAGNETIC SPECTRUM



SOLAR IRRADIANCE



TYPES OF UV LIGHT

UV radiation accounts for only a small portion of the solar spectrum (~5%). How much of this reaches your part depends on where you live in the world, and it varies from year to year. One measure of solar energy is the Langley(Ly), a unit of solar energy distributed over a specific area.

- UV-A (315nm – 400nm)
  - Long wavelength UV related to tanning and premature skin aging
  - Contributes to the degradation of many polymers
- UV-B (280nm – 315nm)
  - Shorter wavelength UV, and the most damaging.
  - Prolonged exposure causes sunburn
  - Fortunately, much of UV-B is absorbed by our Ozone layer
  - Most polymers are very sensitive to UV-B
- UV-C (200nm – 280nm)
  - Shorter still and contributes to degradation in some polymers
  - Used for germicidal applications

RESULTS OF UV EXPOSURE

Polymer degradation begins when UV light from the sun is absorbed by various chemical groups in the polymer. This process damages the polymer, breaking molecular bonds, reducing polymer into smaller fragments.

Lowers Molecular Weight

- **Irreversible chemical reaction**

Loss of Mechanical Properties

- Elastic behavior
- Strength, stiffness, and impacts

Change in Appearance

- Color (fading or yellowing)
- Crazing/cracking
- Chalking (white residue on surface)
- Loss of gloss

Change in Dimensions

- **Warp materials**

MATERIAL SELECTIONS

As with any other performance attribute, we begin with the application and the mechanical/chemical performance requirements. Where will the part live and what will it be required to do.

These requirements will limit our formulation choices. Expectations for weathering or UV performance further refine the selection process.

Everything influences performance!

- Polymer(s)
- Additives and fillers
  - Glass, mineral, Flame retardants
- Colorants
- Stabilizers

TYPES OF UV LIGHT

Examples of UV wavelength sensitivity by polymer

- Polyethylene 300-340 nm
  - Prone to yellowing and embrittlement
  - UV stable grades greatly improve performance with many extended outdoor applications
- Polypropylene 290-370nm
  - Prone to yellowing and embrittlement
  - UV stable grades have allowed expansion into a variety of outdoor applications including automotive
- ABS 300-390nm
  - Typically, unsuitable for outdoor applications without coating/paint
  - UV stabilized grades are available for limited exposure applications
- Polycarbonate 280-310nm
  - Degrades with pronounced discoloration and increasing Haze
  - UV resistant grades are available along with surface treatments for specific applications
- Nylon 290-315nm
  - Yellows significantly with embrittlement
  - UV stabie grades available, with carbon black formulations providing some of the best performance

ADDITIVES AND FILLERS

Additives and fillers can influence the UV weathering performance of your parts.

- Functional additives
  - Flame retardants
  - Wear and friction
  - Impact modifiers
  - Anti-static or conductive
- Fillers and reinforcements
  - Glass fiber, beads
  - Other fibers
  - Minerals

COLORANT CHOICES

Organic Colorants

- Pigments and dyes
- Limited heat stability (300 °C max)
- High color strength
- Generally lower Light fastness
  - Relative to Inorganic options
  - Evaluated on individual basis
  - High performance colorants

Inorganic Pigments:

- Easy to disperse
- Heat stable
- Color strength
  - Relative to organic options
  - Varies with hue
- Improved light fastness

UV STABILIZERS

UV stabilizers have been developed to improve the performance of polymers and polymer compounds by inhibiting the degradation process.

- Ultraviolet absorbers
  - Function by competing with polymer to absorb UV and change it into less harmful infrared radiation (heat), which is dissipated through polymer matrix
  - Benzophenones, Benzotriazoles, and carbon black are common absorbers
- Hindered Amine Light Stabilizers (HALS)
  - Trap free radicals formed during the degradation process
  - Wide structural differences between grades
  - Provide some long term thermal stabilization
- Quenchers
  - Function by transferring energy absorbed during photo-oxidation
  - Nickel quenchers contain heavy metals and impart color
  - Less effective than Hindered Amine Light Stabilizers
- All function by different mechanisms and are often combined for synergistic benefits. HALS + absorber is a common solution for colored systems.

UV DEGRADATION AND STABILIZATION

UV

Plastic Material

Absorption of UV radiation ← UV Absorbers

Degradation to polymer chains (reduction in properties) ← Light Stabilizers

Shorter Service Life ← Or Longer Life!

HOW DO WE FORMULATE?

- We review the application and select polymer and reinforcements and/or functional additives to meet the performance objectives of the application and the environment in which it will live.

- Colorants are chosen to achieve the aesthetic goals while balancing both mechanical properties and weathering expectations.

- UV stabilization builds on the good choices already made during the compound formulation and colorant choices, supporting a synergistic system to achieve the desired weathering performance.

- Balance is key and every component contributes to part performance and application success

WHY AND HOW DO WE EVALUATE UV PERFORMANCE?

- Why is UV testing necessary?
  - Testing is done to predict expected service life

- How is UV performance evaluated?
  - Materials can exposed to natural or artificial UV radiation
  - Material properties are evaluated based on change or property retention

NATURAL TESTING

Outdoor exposure is conducted at specific test sites

- Florida (subtropical climate): high amount of sunlight, high year around temperatures, high humidity, and abundant rainfall
- Arizona (desert climate): high amount of sunlight, high year around temperatures, and lower humidity

Environmental Factors

- Solar irradiance, ambient temperature, humidity, rainfall, pollution

Not accelerated

Not reproducible as climate changes year over year

Accelerated test methods available

- Mirrors to concentrate the light
- Water spray to increase humidity

ARTIFICIAL WEATHERING

Artificially exposes materials to UV radiation, many light sources available:

- Most common are Xenon Arc and Fluorescence

Accelerated

Reproducible

- Continuously cycling samples through UV radiation, water spray, temperature, and various humidity to simulate outdoor exposure

Many light filter combinations possible allowing for different cut off wavelengths. Filters which allow for shorter wavelengths of UV light to pass are more aggressive than natural sunlight

CORRELATION

- How many accelerated hours equals one year outdoor exposure?
  - "There is no direct correlation"
  - This question is extremely challenging to answer given all the variables and changing weather patterns
- How do you determine if you material will be suitable for your outdoor application?
  - Industry Standards: SAE J2412, SAE J2527, ASTM G 155, ISO 4892-2
  - Select an test method that is appropriate for your environment
  - Standard Reference Materials (SRM) can be used to help predict service life of part. These can be used as a control. A SRM is a material that has been thoroughly tested and has known behavior.
  - Better performance in accelerated artificial weathering = better performance in real world in most cases

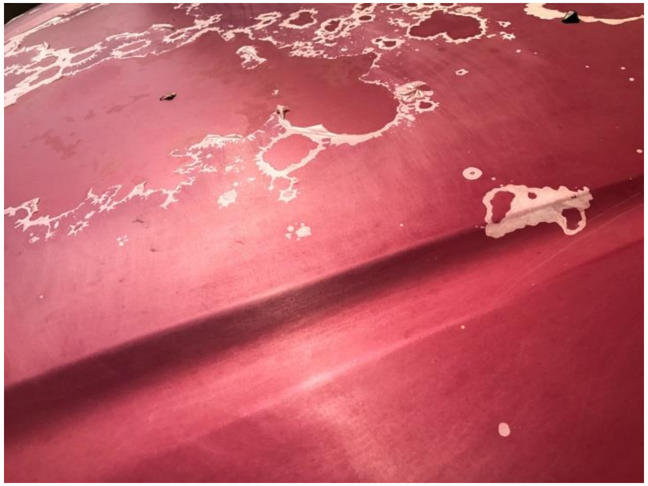
VISUAL EVALUATION

Color Change

- Color properties are measured using spectrophotometer
- Color change is reported in delta values in a specific color space
  - DEcmc is a value that reports total color change, this is only one of many color spaces available.

Fading

- Measured by AATCC Gray Scale.
- A scale of 1 through 5
  - A value of 5 having no fading and 1 significant fading
- This is a visual examination of the weathered specimen next to reference standard.



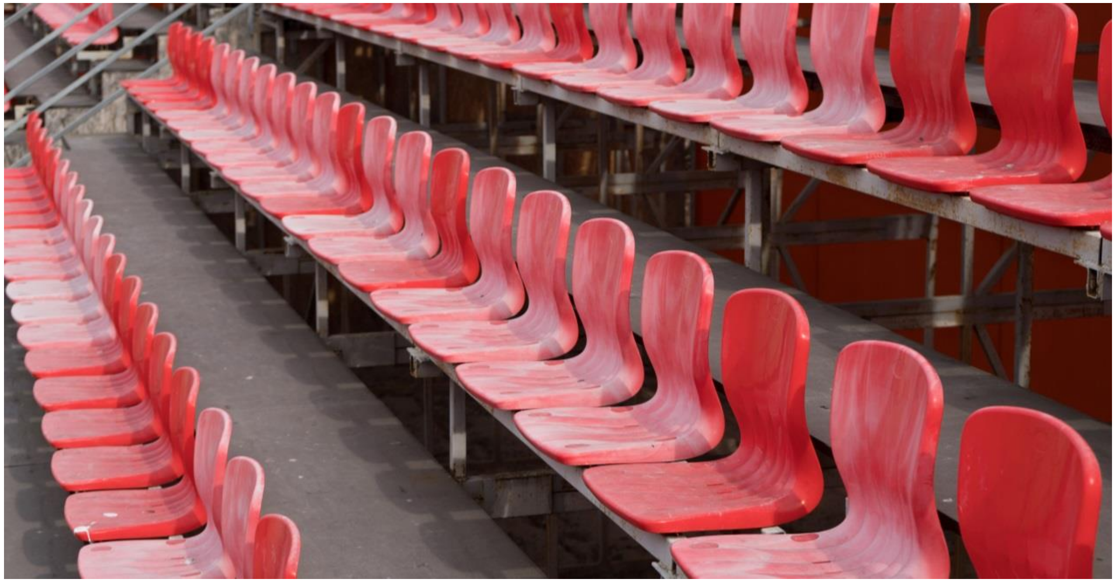
VISUAL EVALUATION

Gloss

- Measures the amount of light reflected by a sample
- Loss in gloss can be a sign of material degradation

Visual examination of surface

- It's important to visually analyze the sample.
- This can help determine failure mode. Is the specimen crazing, chalking, or blistering?



PHYSICAL EVALUATION

Tensile Strength

- Measure of force per unit area needed to break specimen when pulled at a specific rate from both ends

Flexural Strength

- Measure of a material’s resistance to deform under a load

Impact Strength

- Measure of the material’s toughness when impacted abruptly

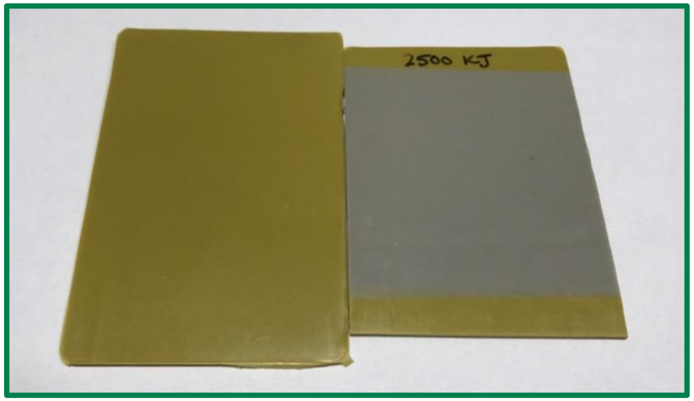
Pass/fail criteria is specified by customer

- Standard pass/fail criteria involve a material maintaining a specific amount of its initial properties

CASE STUDY

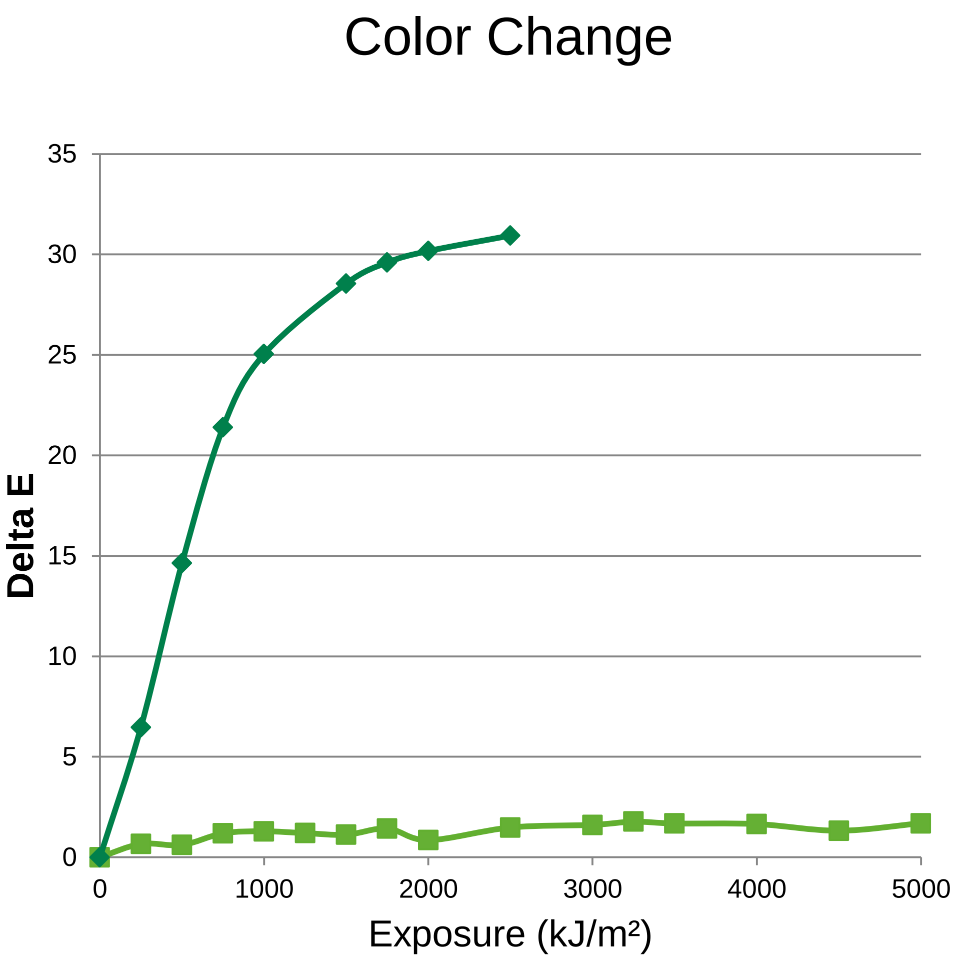
- Market:Consumer Goods
- Application: Lawn and Garden
- Problem: Continuous outdoor use in subtropical weather (>10 year life expectancy)
- Solution: UV stabilized PE in many custom colors
- Test Method: SAE J2527 extended filters

CASE STUDY

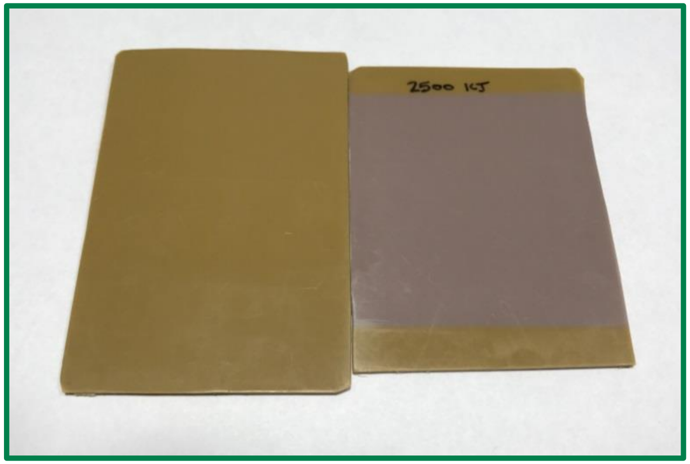


Olive Drab Competitive Material

Olive Drab RTP Material

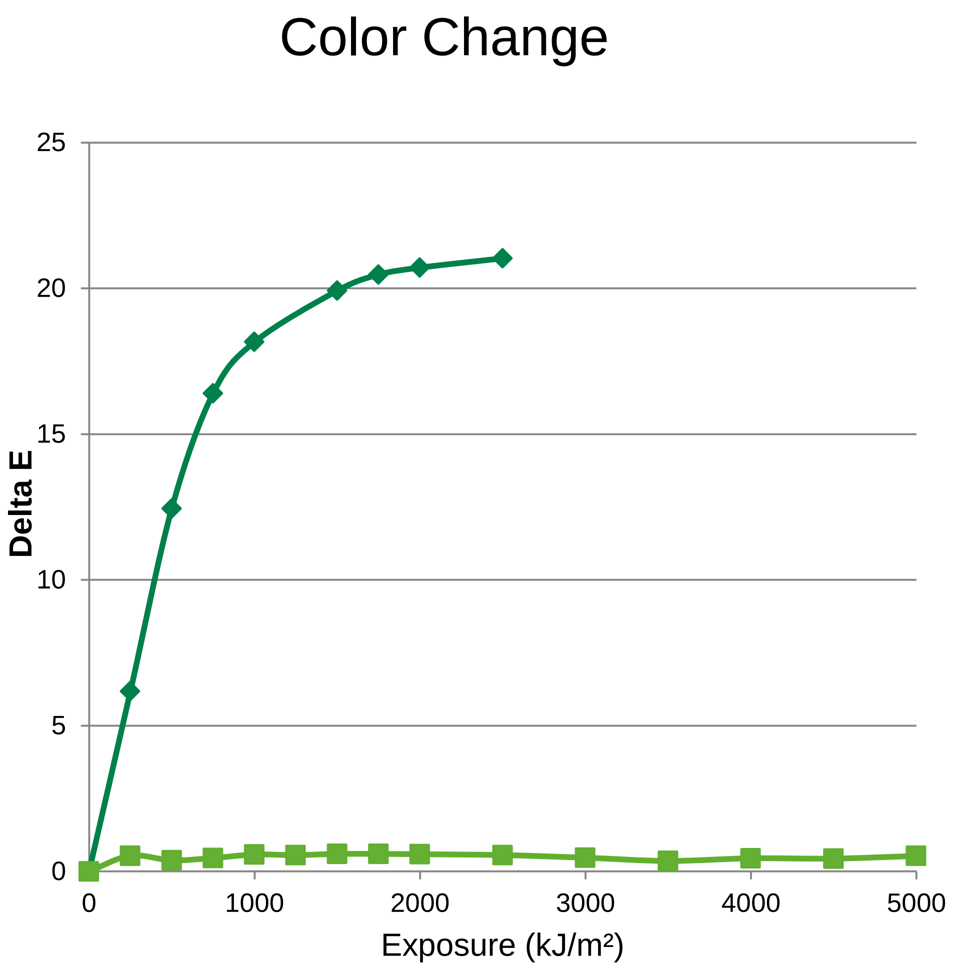


CASE STUDY



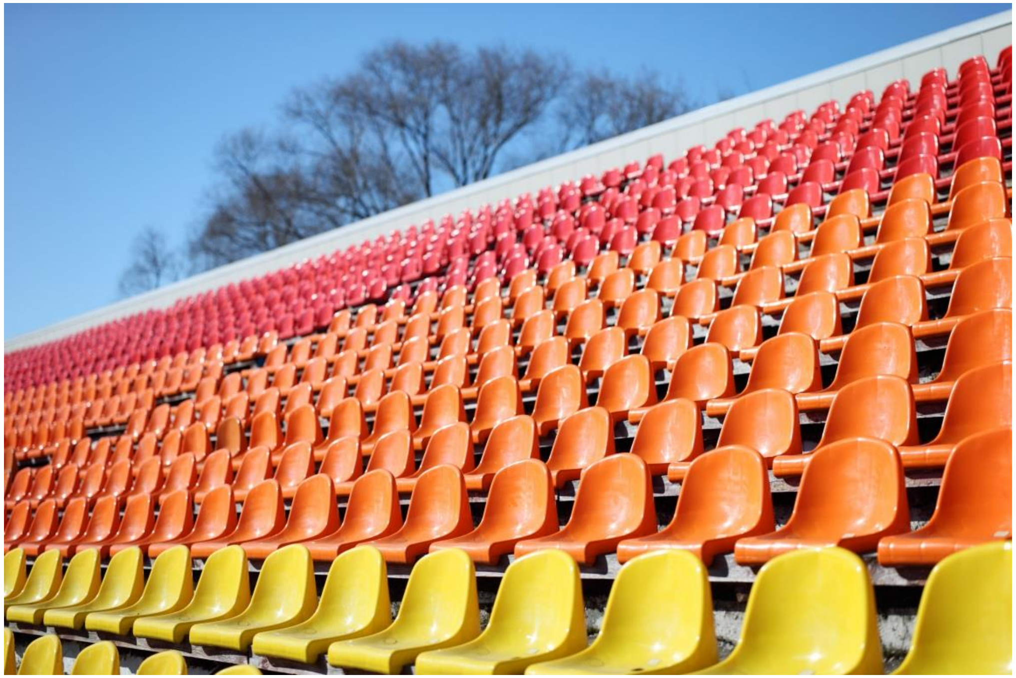
Brown Competitive Material

Brown RTP Material



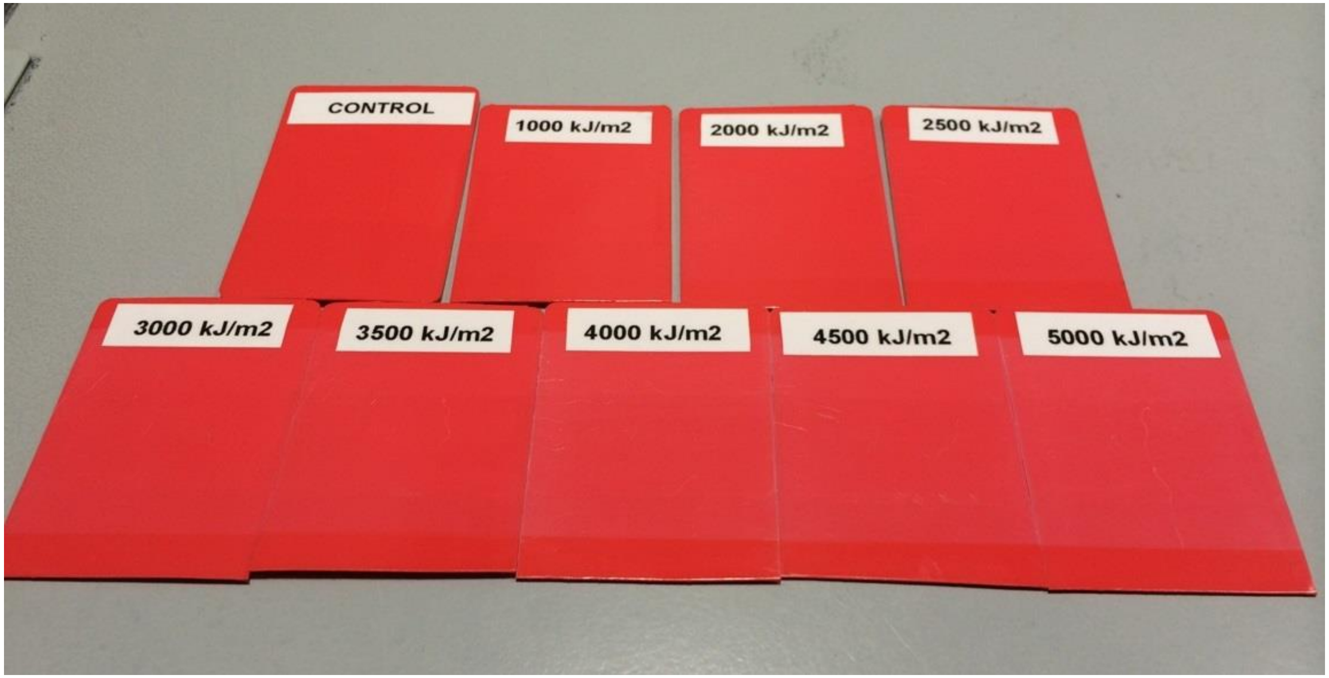
CASE STUDY

- Market:Industrial
- Application: Outdoor Furniture
- Problem: Chromatic colors with continuous outdoor use
- Solution: UV stabilized PE with lightfast colorant package
- Benefit: Offered UV + Custom Color Masterbatch
- Test Method: SAE J2527 extended filters



CASE STUDY

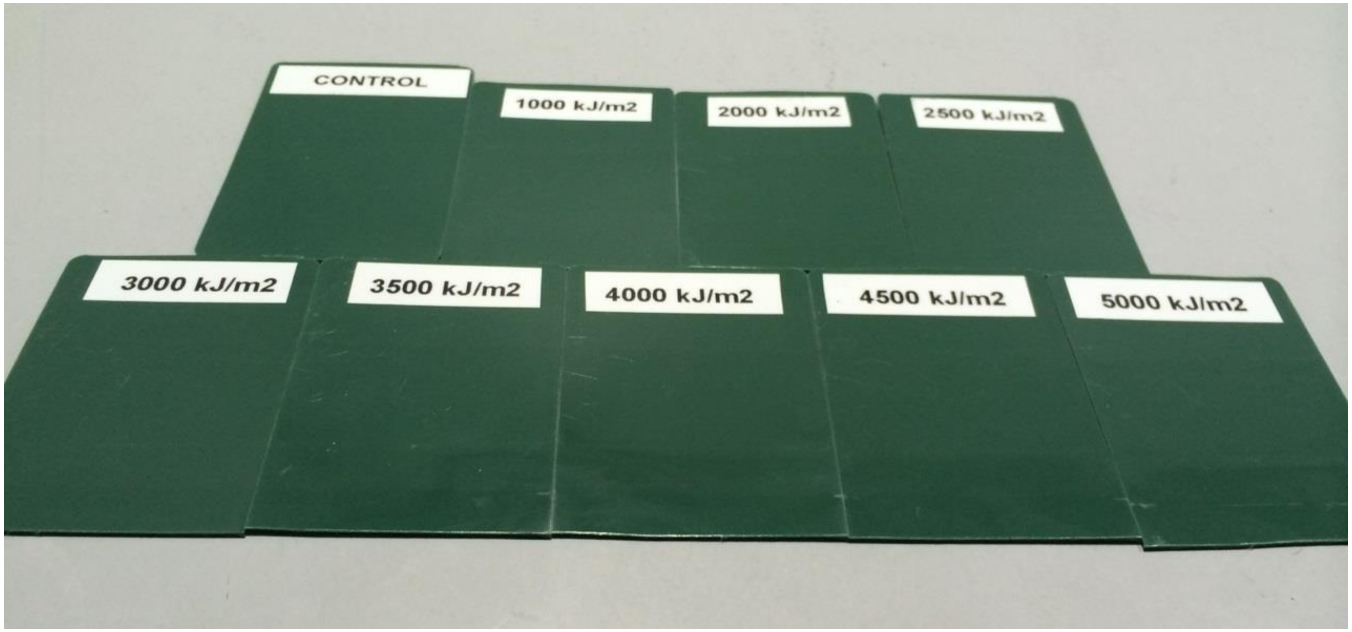
Exposure (kJ/m²)	ΔE_{CMC}
Control	0.00
1000	0.48
2000	1.47
3000	2.92
4000	5.14
5000	5.65



Gloss Retention 100% at 5000 kJ/m^2

CASE STUDY

Exposure (kJ/m^2)	ΔE_{CMC}
Control	0.00
1000	0.36
2000	0.47
3000	0.47
4000	0.73
5000	0.65



Gloss Retention 100% at 5000 kJ/m^2

CONCLUSION

- RTP Company supplies innovative colors and functional additives
- There are several environmental factors that shorten the life span of material
- Proper polymer matrix and UV stabilization is critical to life expectancy of the part
- Appropriate weather testing is needed to help validate material
- RTP Company has experience working with short term, long term, intermittent, and continuous outdoor exposure applications
- Weathering performance should be a conversation

Thank You!

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