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Improving Infrared Reflectance of Greenhouse Films

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Our Discussion Today

UV Reflectant White Pigment for Agricultural Film Applications

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Altiris® Pigment - Crystal modified TiO2 with dense silica coating

- High IR reflectance
- Super durable coating designed for prolonged exterior use

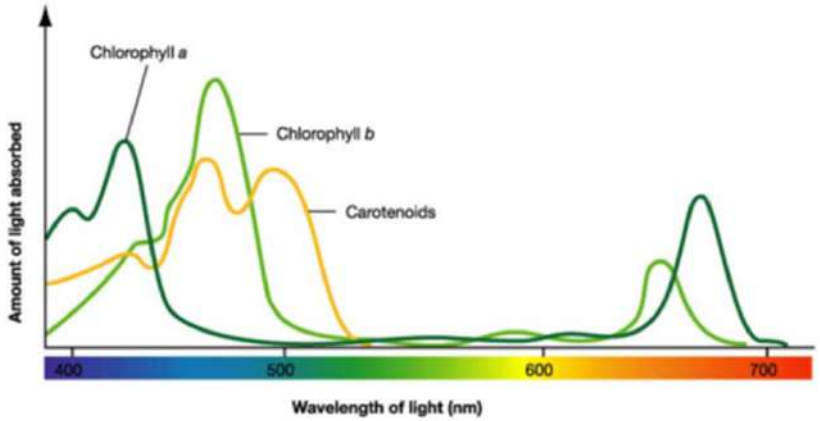
Agricultural Film Applications – Examples

Temperature Control

The market for multi-layer barrier films in agricultural applications is constantly increasing! Popular applications include:

- **Greenhouse and Tunnel films**
  - Provide condensate control, reduced nighttime heat loss (IR), **reduced daytime heat gain**, **controlled light diffusion and optimized UV Light transmission**
- **Silage films (both stretch film & silo film)**
  - Reduced oxygen transmission rate (OTR) increases quality of stored silage. **Controlled heat accumulation**
- **Mulch films**
  - Used to modify soil **temperature**, limit weed growth, prevent moisture loss, reduce fumigant evaporation rate

Greenhouses provide benefits



- Greenhouses provide a safe and controlled environment for plants to grow
  - Moisture levels can be regulated to ensure the plants can still transpire
  - Pest levels can be monitored and controlled
  - Crops are protected from adverse weather conditions
- UV, visible and infrared light is still able to pass through the film to the plants inside
  - UV light is required for insect pollination of flowers but is harmful to the plastic film
  - Visible light drives photosynthesis (see graph opposite)
  - Infrared energy in moderation enables optimum growth temperatures

…but problems can occur

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▶ Overheating

- If too much infrared energy passes through the film (ex. summer months, hot climates) the interior can become too hot and plants can suffer stress
- Stressed plants can wilt thereby reducing the surface area of their leaves which reduces their ability to absorb the energy they need from the sun's visible light
- Enzymes each have an ideal temperature range, too cold or too hot and they lose efficiency or denature. Maximum plant enzyme efficiency means faster plant growth

▶ Scorching

- Many plants need protection from direct sunlight either by shading or by diffusing the light passing through the film

▶ Condensation

- Damp, still air promotes mold and mildew growth

Weatherable Films – Pigments

White Pigment (TiO2) Grade Choice

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- **There are many different types & grades of TiO2 available.**
  - TiO2 grades are surface coated to make them more stable outdoors.
  - Untreated grades of TiO2 can actually accelerate the degradation of film outdoors
- **Choice of TiO2 grade based on a number of factors:**
  - Geographic location
  - Plastic resin type & film thickness
  - Additives: ultraviolet stabilizers, antioxidants, etc.

These variables make it almost impossible to produce one film for all climates, geographic regions, crops and service lifetimes!

Color - reflectance spectra of TiO_2

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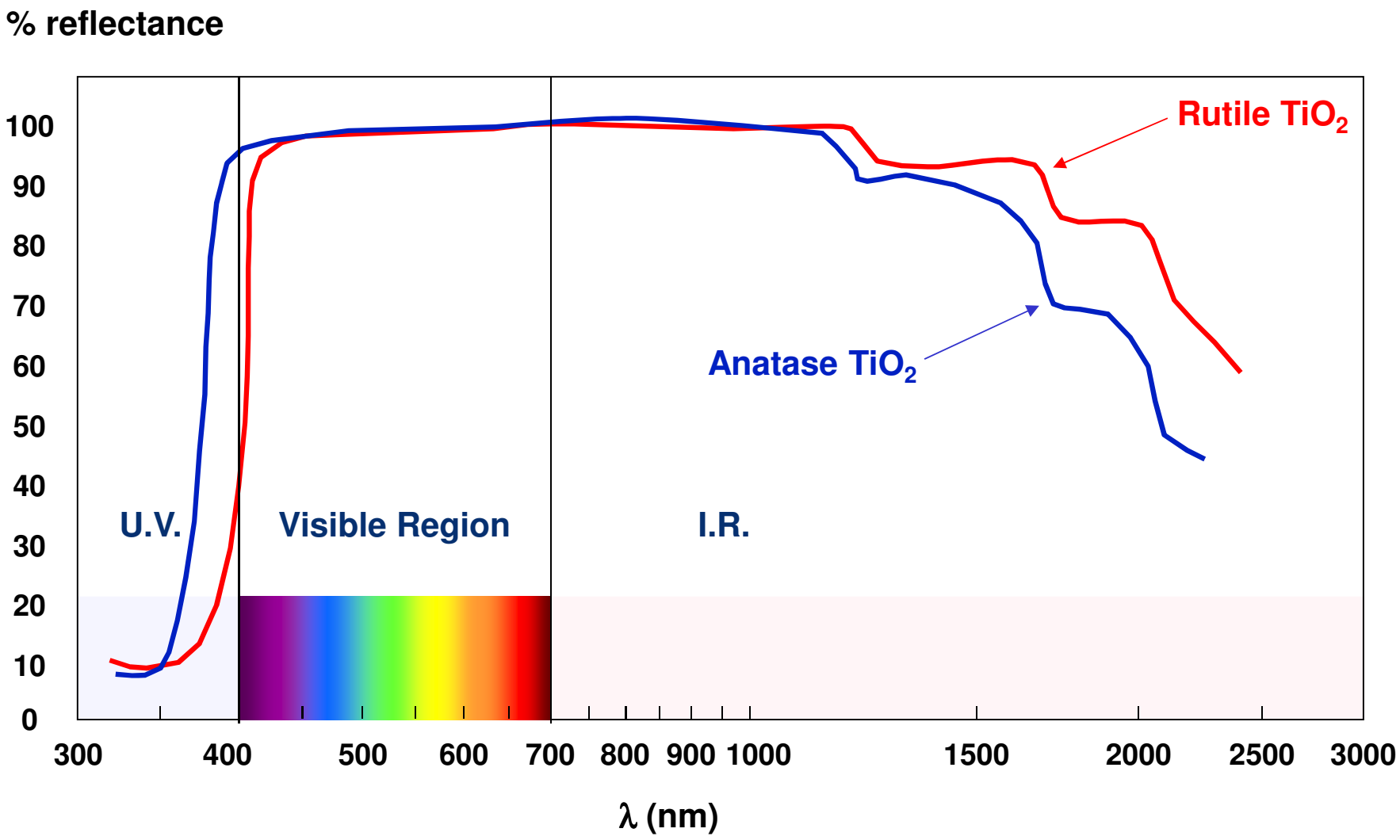

ALTIRIS® infrared reflecting pigments

Managing reflectance to improve product durability

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Sunlight is made up of three parts:

▶ Ultraviolet (UV)

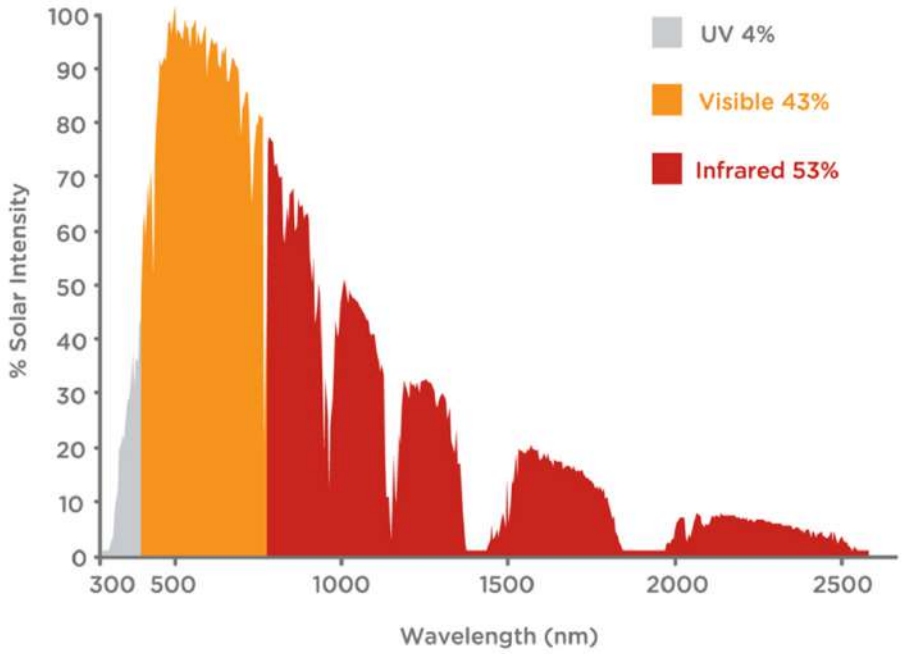
- Smallest part of the Sunlight spectrum
- Causes film to break-down (photodegradation)
- Organic and inorganic additives used to control plastic degradation

▶ Visible (VIS)

- Less than 50% is the visible part we see
- Causes heating of the polymer, leads to warping, micro cracking or embrittlement (thermal degradation)

▶ Infrared (IR)

- Over half the sun's power is in the infrared
- Invisible but adds to the heating problem



Grey Ore to White Pigment

TiO2 Manufacture

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$FeTiO_3$

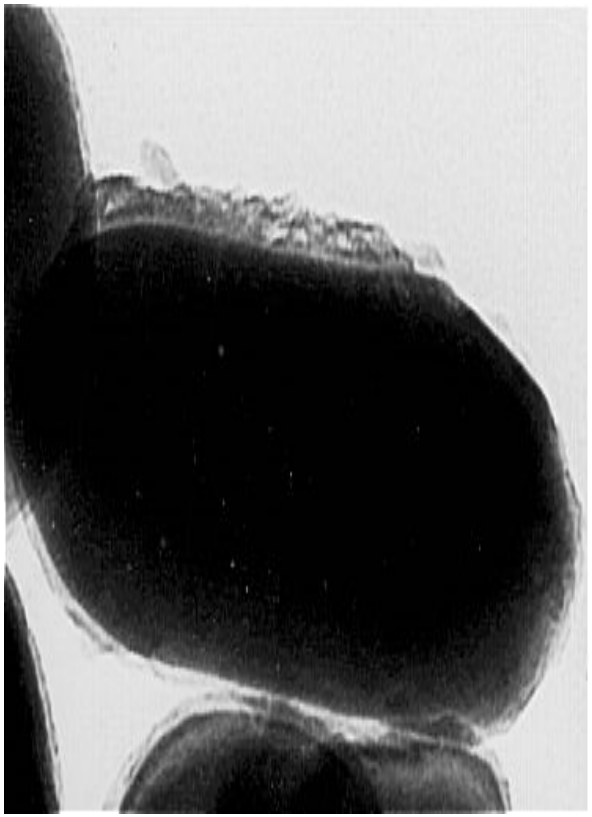
TiO_2

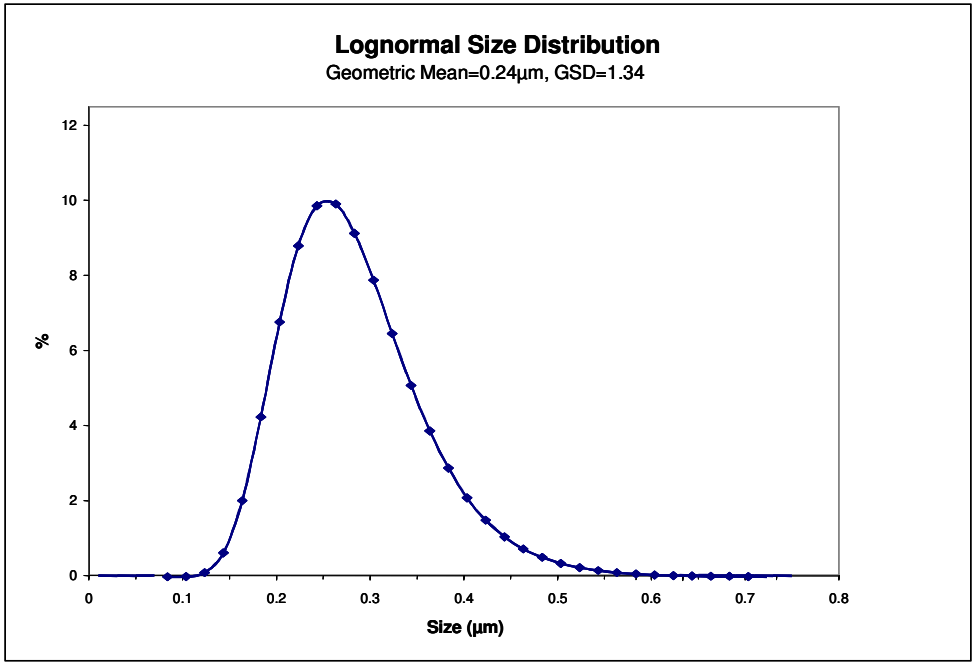
Ilmenite or Rutile

TiO_2

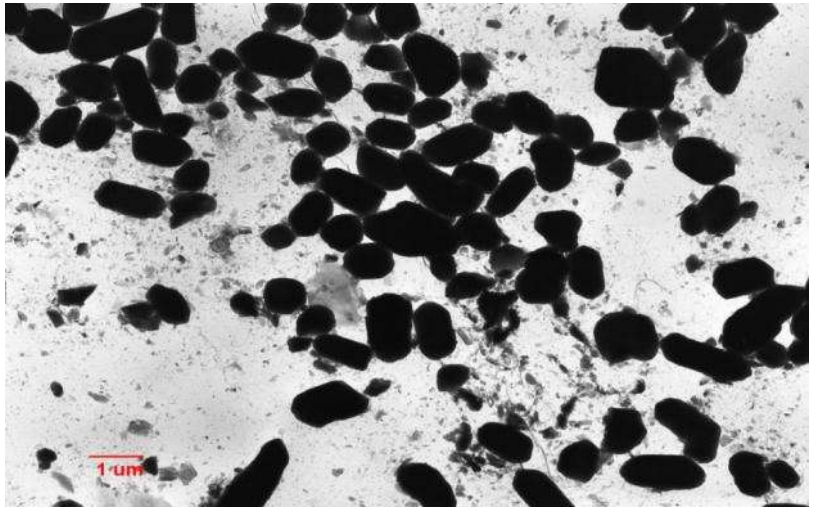
TiO2 Pigment design
Crystal Size

- **A crystal is defined as the smallest unique particle of TiO_2**
  - The crystal size and size distribution will determine the optical characteristics of the TiO_2 pigment

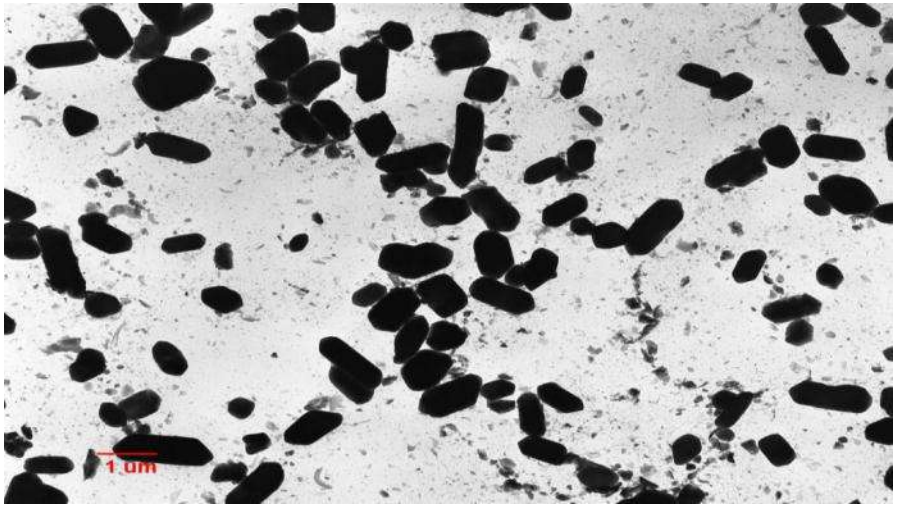




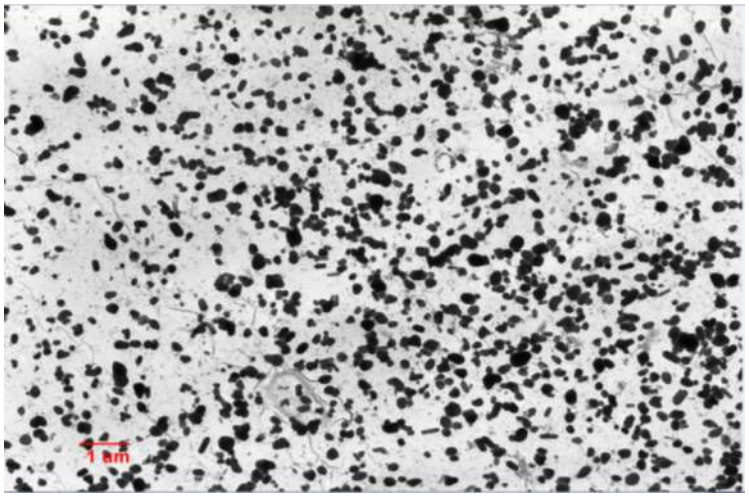
ALTIRIS® pigment crystal size measurement



ALTIRIS® 800 TiO2 pigment



ALTIRIS® 550 TIO2 pigment



Pigmentary rutile TiO2

ALTIRIS® infrared reflecting pigments

Engineered for maximum impact

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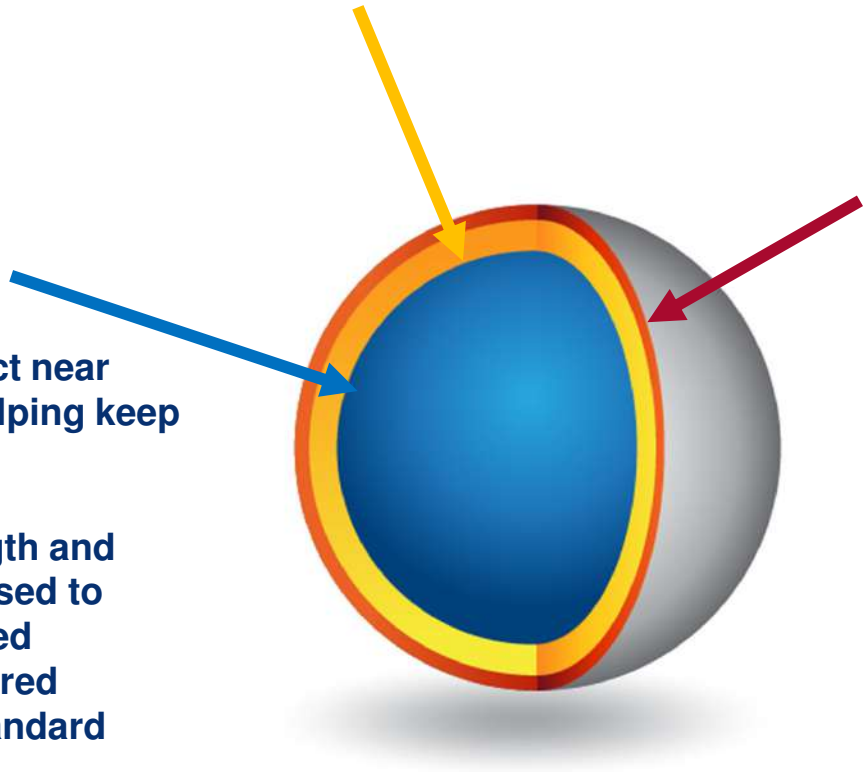
Dense silica shell

- Ensures that ALTIRIS® pigment has high durability



Large titanium dioxide particle

- Optimised to reflect near infrared energy helping keep system cooler
- Has low tint strength and therefore can be used to improve the infrared reflectance of colored systems unlike standard titanium dioxide

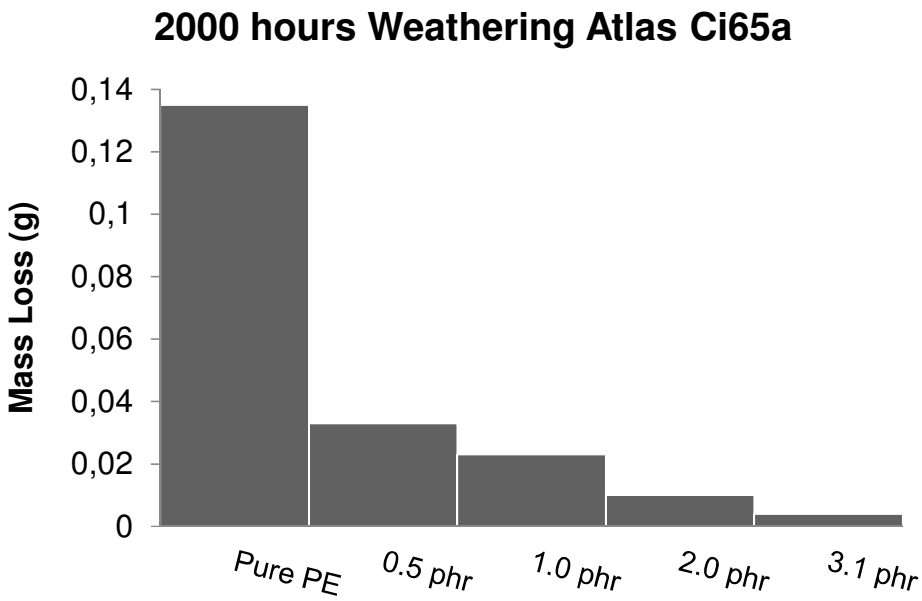
Alumina coating

- Facilitates excellent dispersion

ALTIRIS® pigment Greenhouse films

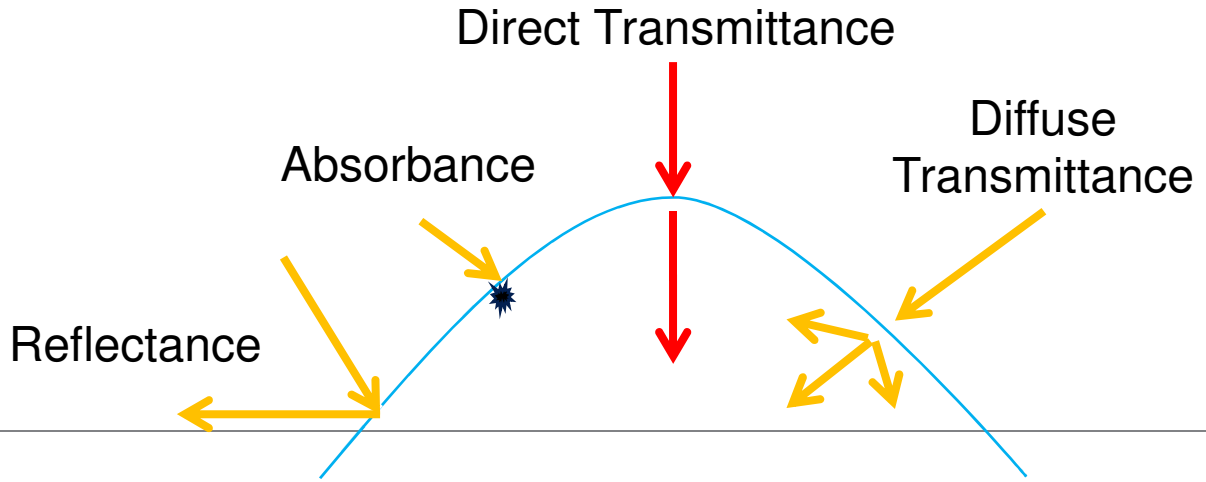
ALTIRIS® pigment benefits

- ALTIRIS® 800 pigment reflects and absorbs UV light
  - UV light although helpful for insect pollination, can cause damage to polymer films if it is absorbed
  - ALTIRIS® 800 pigment can be used to reflect / absorb UV radiation, protecting the film
- A dense silica coating is applied to ALTIRIS® 800 pigment limiting photocatalysis to minimise mass loss from the polymer, thereby helping to enhance the product's lifetime



ALTIRIS® pigment benefits

- **A greenhouse film with added ALTIRIS® allows solar radiation to be 'dimmed' with minimal impact on the wavelength distribution.**
  - The light reaching the plants looks like sunlight
- **ALTIRIS® helps regulate the amount of infrared light from the sun entering the greenhouse**
  - Greenhouses could be used all the year round for optimal crop yields
- **Diffusing the sunlight (Vis & IR) helps reduce scorching**
  - The high refractive index of ALTIRIS® promotes a high level of diffusion at relatively low concentrations



What happens to the light entering a greenhouse film when ALTIRIS® pigment is added?

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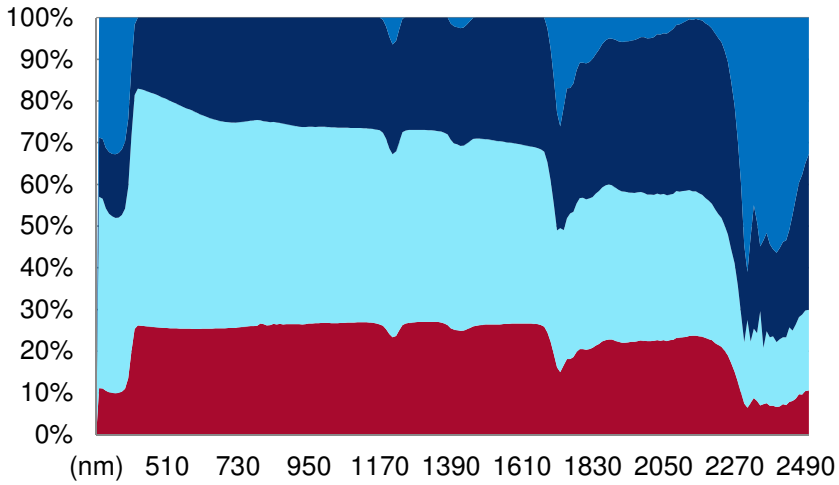
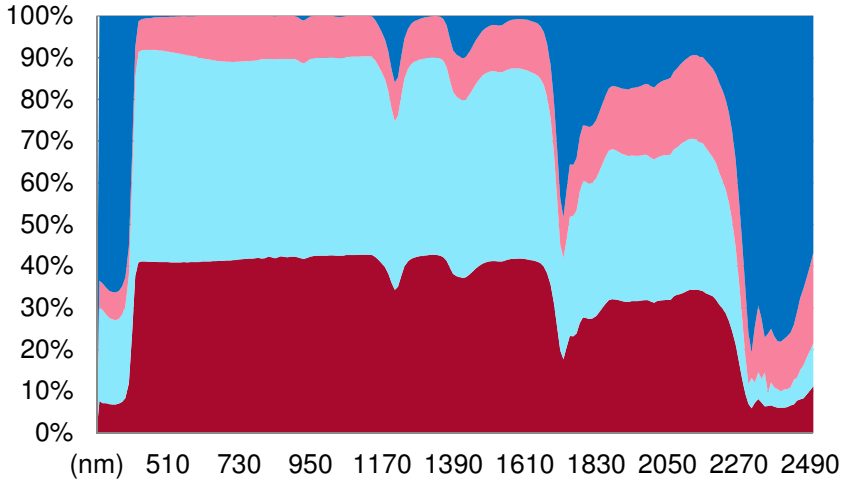
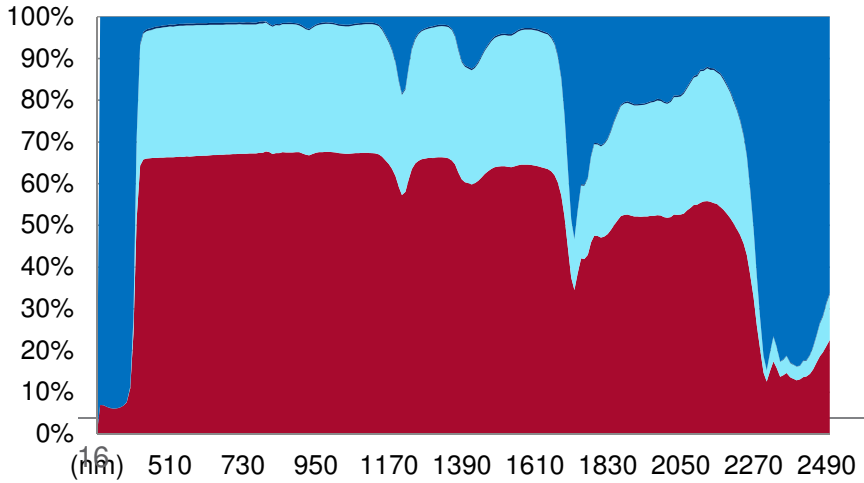
0.5 phr ALTIRIS(R) 800



1.0 phr ALTIRIS(R) 800



5.0 phr ALTIRIS(R) 800



Key:

Absorbance

Direct Transmittance

Diffuse Transmittance

Reflectance

ALTIRIS® pigment
Two case studies in Turkey

Summer Greenhouse

Overview

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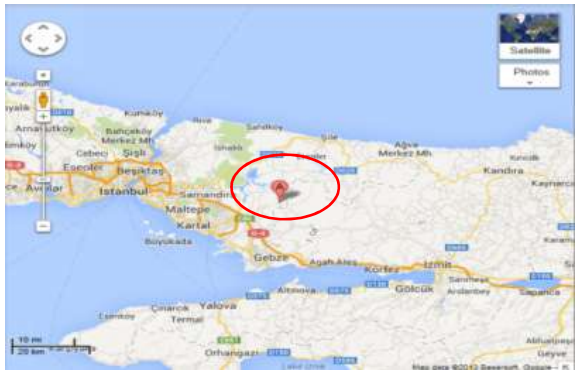
	Film contains ALTIRIS® 800 pigment	Film control
Size	280 m^2	280 m^2
Film used	400 m^2	400 m^2
Resin	Polyethylene	Polyethylene
Thickness	• 180 microns total (co-extrusion) • 50 microns outer layer contains ALTIRIS®	190 microns total
ALTIRIS® loading	• Masterbatch 50% conc., 2% added to film • 1% total in the 50 micron layer	• Not-applicable
Timescale	• July to November • 88 days data collected	• July to November • 88 days data collected



Location

Greenhouse film with ALTIRIS® 800 pigment

Greenhouse film control

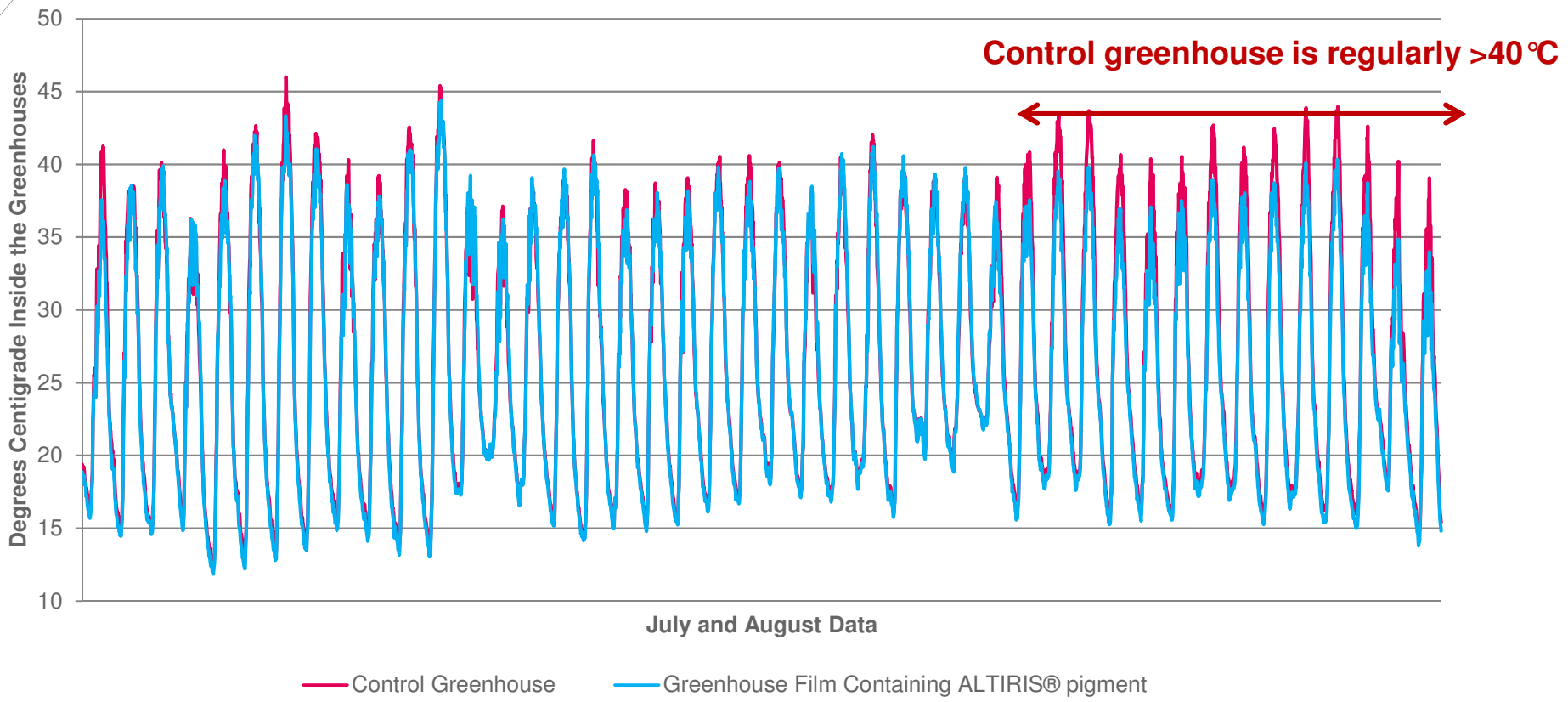
Summer Greenhouse

Test results

	Film with ALTIRIS® 800 pigment	Film control (No Altiris® pigment
Film production	• No issues with film extrusion	• No issues with film extrusion
Tomato production	• Tomato size medium to large • Very uniform shape of tomatoes	• Tomato size small to medium • Shape of tomatoes not very uniform
UV light	• Approximately 32% UV transmission	• Approximately 90% UV transmission
Visible light	• Only 3% loss of photosynthetically active radiation (PAR) through the film compared to the control	
Infrared light	• 6% less near infrared light has been transmitted through the greenhouse film than the control	
Interior temperature	• 19 hours the temperature was >40 ℃ (across July and August) • 139 hours the greenhouse was <6 ℃ (across October and November)	• 64 hours the temperature was >40 ℃ (across July and August) • 120 hours the greenhouse was <6 ℃ (across October and November)
Relative humidity	• Did not reach 100% relative humidity (RH)	• Did not reach 100% relative humidity (RH)

Summer Greenhouse

Interior greenhouse temperature comparison



- Owner sought to minimize excursions above 40℃
  - Greenhouse built with control film was hotter at the peak times of the day than greenhouse built with ALTIRIS® pigment in the film
  - Control greenhouse consistently peaked above 40℃ in August. The greenhouse containing ALTIRIS® pigment in the film did not

Photographs

Greenhouse film contains
ALTIRIS® 800 pigment

Greenhouse film Control
(No ALTIRIS® 800 pigment)

Photographs taken in the middle of the trial

Greenhouse film contains ALTIRIS® 800 pigment

Greenhouse film Control

Photographs at the end of trial

Greenhouse film contains ALTIRIS® 800 pigment

Greenhouse film Control

ALTIRIS® pigment

Diffuse + direct transmission measurements

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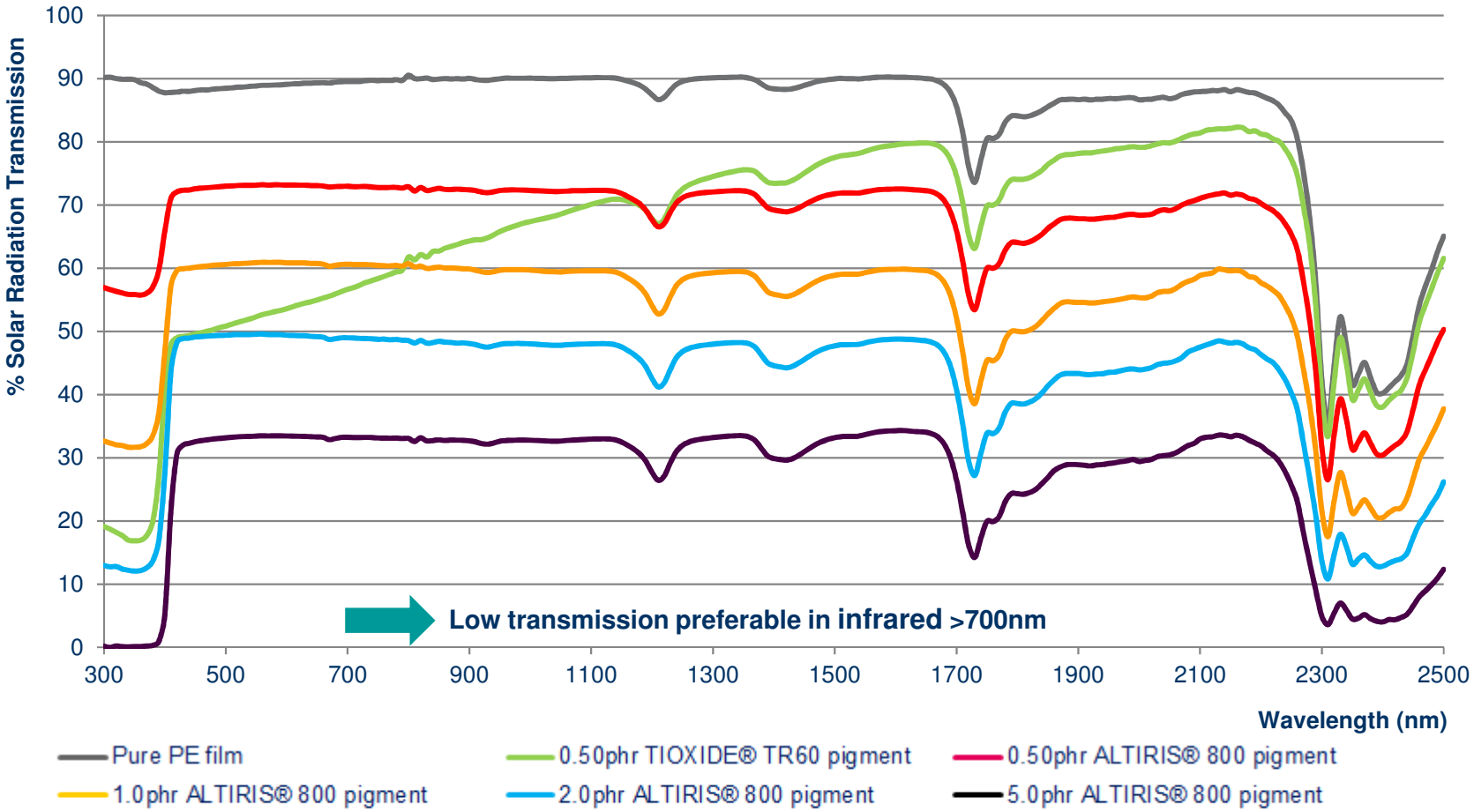
High transmission preferable in visible <500um 650-700nm

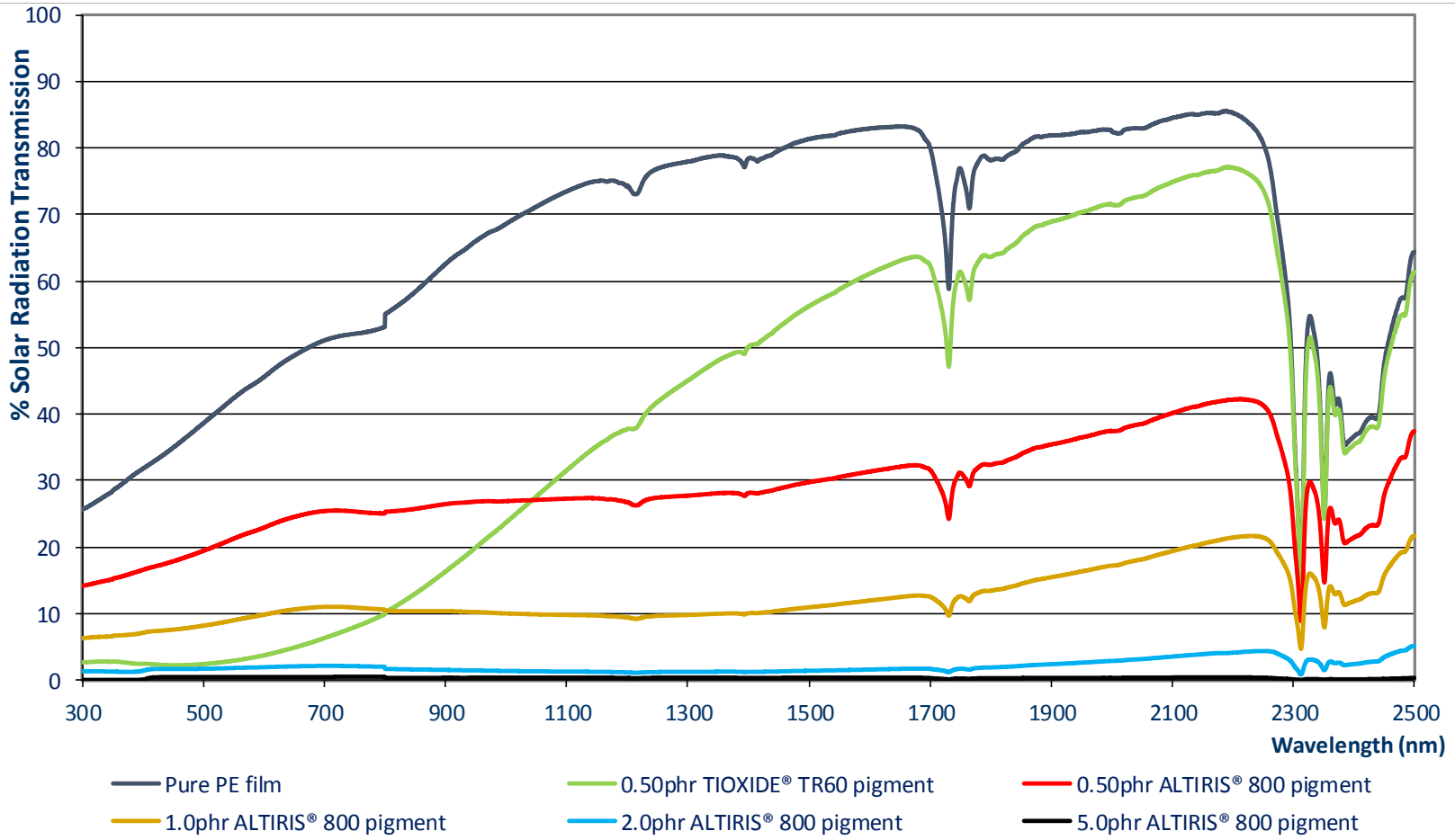


When ALTIRIS® pigment is used in a greenhouse film, the film promotes a high level of diffusion

Graph shows 180 micron PE Films Cary Transmission Scans using DRA Sphere and ccomparisons are with TIOXIDE®TR60 pigment

ALTIRIS® pigment

Direct transmission measurements



Use of ALTIRIS® pigment in a greenhouse film promotes a high level of diffusion and therefore has low direct light transmission

Graph shows 180 micron PE Films Cary Transmission Scans using DRA Sphere and ccomparisons are with TIOXIDE®TR60 pigment

ALTIRIS® pigment

Reflectance measurements over black substrate

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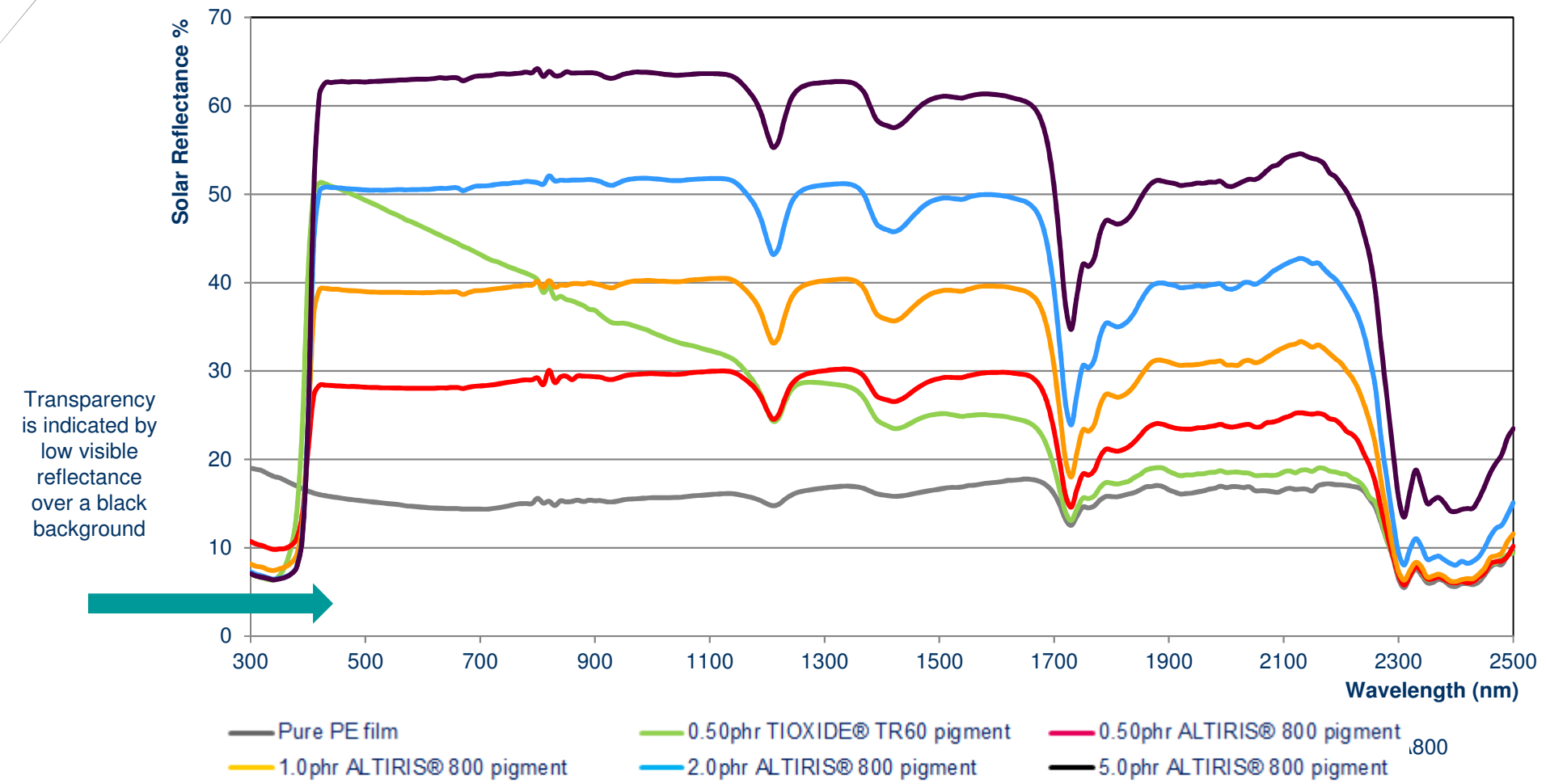

Transparency is indicated by low visible reflectance over a black background

Graph shows 180 micron PE Films Cary Transmission Scans using DRA Sphere and ccomparisons are with TIOXIDE®TR60 pigment

Summary of Spectral Data

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Use of ALTIRIS® TiO2 pigment in Greenhouse film:

- **Allows the solar intensity to be dimmed within the Greenhouse.**
  - Retaining the spectral distribution that plants have learned to thrive on
- **Assists in blocking UV and extends film life**
- **Increases the diffuse component of visible transmission**
  - Allows photosynthetically active radiation (PAR) to reach more leaf surfaces
- **Increases the diffuse component of near infrared transmission**
  - Diluting the heating effect on individual leaves

Thank you

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