Improving Infrared Reflectance of Greenhouse Films

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Hortitec
Our Discussion Today
UV Reflectant White Pigment for Agricultural Film Applications

Altiris® Pigment - Crystal modified TiO2 with dense silica coating

- High IR reflectance
- Super durable coating designed for prolonged exterior use
Agricultural Film Applications – Examples

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

**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
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$_2$

% reflectance

![](image)

U.V.  Visible Region  I.R.

λ (nm)

300 400 500 600 700 800 900 1000 1500 2000 2500 3000

0 10 20 30 40 50 60 70 80 90 100

Rutile TiO$_2$

Anatase TiO$_2$
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

Ilmenite or Rutile → FeTiO3 → TiO2

TiO2
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

- **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

- **Dense silica shell**
  - Ensures that ALTIRIS® pigment has high durability

- **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?

**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

<table>
<thead>
<tr>
<th></th>
<th>Film contains ALTIRIS® 800 pigment</th>
<th>Film control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>280 m²</td>
<td>280 m²</td>
</tr>
<tr>
<td><strong>Film used</strong></td>
<td>400 m²</td>
<td>400 m²</td>
</tr>
<tr>
<td><strong>Resin</strong></td>
<td>Polyethylene</td>
<td>Polyethylene</td>
</tr>
<tr>
<td><strong>Thickness</strong></td>
<td>• 180 microns total (co-extrusion)</td>
<td>190 microns total</td>
</tr>
<tr>
<td></td>
<td>• 50 microns outer layer contains ALTIRIS®</td>
<td></td>
</tr>
<tr>
<td><strong>ALTIRIS® loading</strong></td>
<td>• Masterbatch 50% conc., 2% added to film</td>
<td>• Not-applicable</td>
</tr>
<tr>
<td></td>
<td>• 1% total in the 50 micron layer</td>
<td></td>
</tr>
<tr>
<td><strong>Timescale</strong></td>
<td>• July to November</td>
<td>• July to November</td>
</tr>
<tr>
<td></td>
<td>• 88 days data collected</td>
<td>• 88 days data collected</td>
</tr>
</tbody>
</table>

### Location
![Location map](image)

![Greenhouse film with ALTIRIS® 800 pigment](image)

![Greenhouse film control](image)
### Summer Greenhouse

#### Test results

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

- 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 °C 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

When ALTIRIS® pigment is used in a greenhouse film, the film promotes a high level of diffusion.
**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 comparisons are with TIOXIDE®TR60 pigment.
ALTIRIS® pigment

Reflectance measurements over black substrate

- Pure PE film
- 0.50 phr TIOXIDE® TR60 pigment
- 1.0 phr ALTIRIS® 800 pigment
- 2.0 phr ALTIRIS® 800 pigment
- 5.0 phr ALTIRIS® 800 pigment

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

Transparency is indicated by low visible reflectance over a black background.
Summary of Spectral Data

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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