Physical Features of Plastic Films
Guidelines on Handling Plastic Films

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Motivation

• Retired senior researcher at *Biosystems and Horticultural Engineering Department*, Leibniz University of Hannover, Germany

• Horticultural engineering expert:
  – Greenhouse design
  – Covering materials: glass, plastics
  – ....
  – Consultancy service

• Frequent issue in horticultural industries:
  – *Right choice of plastic film for agricultural application*
Understanding a Technical Data Sheet – Contents

- Producer’s or supplier’s brand
- Features and field of application, e.g. clear / agricultural covering film
- Main compounds of plastic films, e.g. PE, EVA, ...
- Nominal width: 6 m / 8 m / 12 m / 16 m
- Thickness: 100 µm / 150 µm / 180 µm / 200 µm (1 µm = 0.000 001 m)
- Length: as required
- Mass per unit area: kg/m²
- **Tensile strength**
- **Elongation at break**
- **Durability**
- Falling weight test in area / in fold
- Creep — elongation under continuous strain by load and time
- **Transmissivity for visible light (better: PAR) and UV radiation**
- **Haze**
- **Transmissivity for heat radiation, thermicity**
- **Anti-fog behaviour**
Components and Manufacturing of Polyethylene (PE) Films

- Chains of monomeres in material
- Polymere family: thermoplasts
- Basic material (PE) with **additives**, e.g.
  - Processing aids
  - Colouring, transparency
  - UV stabilisation
  - Anti-fog or antistatic behaviour, etc.
- Processing in **extruders**
  - Mixing of resins (pellets, granules)
  - Plastizising by temperature and pressure
  - Coextrusion (3 to 5 layers)
- **Film blowing**
- Coiling and cutting

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Dr.-Ing. von Elsner - Plastic Films
Universal testing machine
Specimen: 140 mm x 10 mm*
Room temperature: 23 °C
Extension velocity: 500 mm/min

Tensile stress, MPa | kg-load at 10 mm strip*  
150 µm film | 180 µm film
≥ 16 | ≥ 2.4  
≥ 16 | ≥ 2.88

Tensile strain, elongation at break, %
150 µm film | 180 µm film
≥ 300  
≥ 400

Typical diffuse film:
Typical clear film:

≥ 19 | ≥ 2.85  
≥ 19 | ≥ 3.42

≥ 400  
≥ 500
Tensile Strength and Elongation at Break → Tunnel Installation

**Rules of fastening:**
- Tighten the film to avoid sheet flutter (fatigue fracture!)
- Careful retension of the film in summer (due to temperature elongation)
- Never touch the film with uncut fingernails
- Never step on the film while fastening

**Caution:**
Proof conditions:
- Temperature: 23 °C
- Tension velocity: 500 mm/min

But:
- Installation at ≈5 °C
- Tension velocity: faster!

Result: **film is more sensitive!**
- Strength and strain is lower!
- Danger of film damage
Ageing and Durability

• All plastic materials suffer by ageing
  – some more slowly, some faster

• Main reasons for ageing:
  – UV radiation breaks the chains: photodegradation → UV stabilizers
  – Temperature and other environmental impact
  – Used pesticides and chemical agents
  – ...

• Durability proof = (natural or artificial) weathering test

• Plastic film guaranty for service life: 50% of strain at break
Ageing Test by Artificial Weathering

The impact of solar radiation is often specified by the old-fashioned American unit **Langley** [Ly] or Kilo-Langley [kLy]: 1 kLy = 41.84 kJoule/m² [energy unit per area]

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>Artificial weathering time [h] for expected service lifetime of …</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 year</td>
</tr>
<tr>
<td>70 to 100 kLy/a</td>
<td>1 700</td>
</tr>
<tr>
<td>100 to 130 kLy/a</td>
<td>2 800</td>
</tr>
<tr>
<td>130 to 160 kLy/a</td>
<td>3 900</td>
</tr>
</tbody>
</table>

An average year in Central Europe yields in 90 to 100 kLy UV radiation.

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Correlation between artificial and natural weathering for polyethylene plastic films

Agricultural covering films — Classification according to artificial weathering time

<table>
<thead>
<tr>
<th>Class</th>
<th>Weathering time [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>≥ 400</td>
</tr>
<tr>
<td>A</td>
<td>≥ 1 700</td>
</tr>
<tr>
<td>B</td>
<td>≥ 3 200</td>
</tr>
<tr>
<td>C</td>
<td>≥ 4 600</td>
</tr>
<tr>
<td>D</td>
<td>≥ 6 000</td>
</tr>
<tr>
<td>E</td>
<td>≥ 7 300</td>
</tr>
</tbody>
</table>

Class defined by EN 13 206
Transmissivity for Solar Radiation $\frac{W}{m^2}$ and PAR $\frac{\mu{\text{mol}}}{s \, m^2}$

- Solar spectrum on earth: 290 nm to 2 500 nm
- Photosynthetic Active Radiation (PAR): 400 nm to 700 nm
- UV-A: 315 to 380 nm | UV-B: 280 to 315 nm | UV-C: 200 to 280 nm
- Solar transmission of PE films: 290 | 320 | 400 nm to 2 300 nm depending on additives
- Typical PE film material transmission
  - direct light, perpendicular beam, dry film: $>87\% \approx$ PAR transmission
  - diffuse light, hemispherical radiation, dry: $>82\%$
Transmissivity for Solar Radiation and PAR

- **Nature of light after passing through PE film:**
  - Clear film: usually direct radiation, stronger shadows
  - Diffuse film: more or less diffuse, scattered light
    - No direct shadows, so better distributed radiation on all leaves,
    - Better overall performance of photosynthesis for space filling cultivations, less overheating and tip burning (e.g. raspberry, cherry)
    - **Haze factor up to 90%** of transmitted radiation

- **UV transmission of films →**
  - Special additives against ageing: HALS – **H**indered **A**mid **L**ight **S**tabilizers
  - Shorter compact habit of plants, dark green leaves, blossoms more colourful
  - Better pollination by bees and bumblebees in closed environments
Heat Transmission through PE Films

• Untreated PE films (e.g. packaging or construction films) transfer ≈ 80% of heat radiation
  – Heat radiation: 5 000 nm to 30 000 nm or 5 µm to 30 µm
  – On the contrary, window glass is intransparent to heat radiation!
• Typical covering films contain EVA (EVA – Ethyl-Vinyl-Acetate, up to 14% in compound, for more flexibility):
  – heat block for ≈ 50%
• Thermic films (thermicity, infra-red efficiency):
  – block up to 90%
• Thermic films act as frost protection (heat radiation to clear sky)
Anti-fog Film – No-drop Film

• On standard PE film, you will find drop condensation
  – Glass offers film condensation
• Droplets will run off at roof angles higher than 16°
  – All nearly horizontally orientated surfaces achieve falling droplets!
  – Gothic arches for tunnel design are better than round arches!
• Falling droplets cause ...
  – wet plant surfaces and by this intensify funghi diseases (e.g. Bothrytis...)
  – mechanically destroy young leaves and blossoms
  – moisten the soil and reduce oxygen in the root area
• Hanging droplets reduce incoming light up to 20%
• Anti-fog films contain additives which migrate over about 2 years to the surface, reduce the surface tension and thus form film condensation
  – Film condensation does not reduce the incoming light
  – On horizontally orientated surfaces, there are still hanging droplets