



# Materials for Oleophobic and Hydrophobic Coatings

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# Applications for Oleo/Hydro-phobic Coatings

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# Covered Topics

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- Sartomer Products
- Surface Energy
- Refractive Index
- Reflection / Anti-Reflection
- Weatherability for UV Applications

# Sartomer Product Properties

|                                | Sartomer Product | F | cps 25°C | Density gm/ml | Surface tension dyne/cm <sup>2</sup> | R.I. @ 589nm | Tg °C [DMA] |
|--------------------------------|------------------|---|----------|---------------|--------------------------------------|--------------|-------------|
| Fluorinated Acrylate Oligomers | CN4001           | 2 | 50       | 1.551         | 22.1                                 | 1.3328       | -12         |
|                                | CN4002           | 2 | 20       | 1.614         | 23.1                                 | 1.3531       | -22         |
|                                | CN4003           | 2 | 160,000  | 1.358         | 24.0                                 | 1.4201       | -27         |
| Compatible Acrylate Monomers   | SR440A           | 1 | 5        | 0.881         | 28.1                                 | 1.4346       | -54         |
|                                | SR484            | 1 | 4        | 0.876         | 28.4                                 | 1.4371       | -57         |
|                                | CD420            | 1 | 8        | 0.931         | 23.7                                 | 1.4321       | 67          |
|                                | SR238B           | 2 | 9        | 1.020         | 33.7                                 | 1.4677       | 43          |
|                                | SR351LV          | 3 | 65       | 1.109         | 36.1                                 | 1.4723       | 62          |
|                                | CD278            | 1 | 43       | 0.989         | 30.3                                 | 1.4355       | -74         |

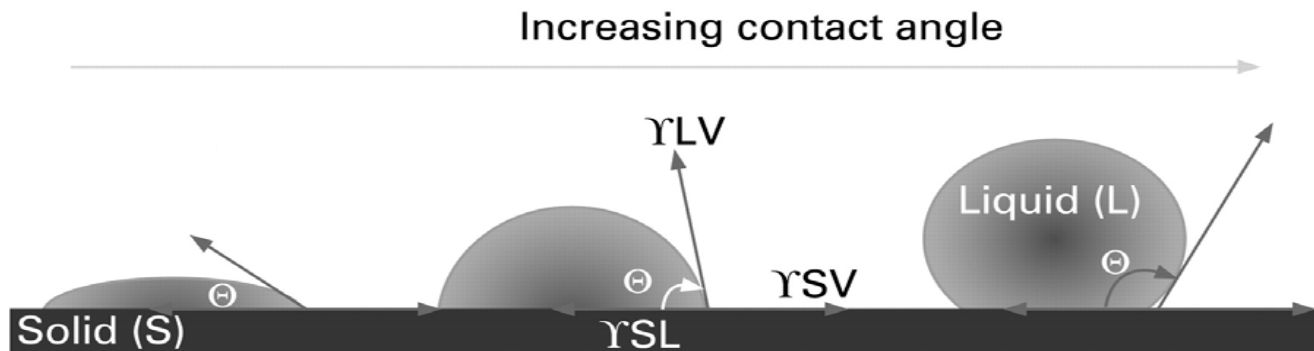
# Fluorinated Product Applications

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- **Hydrophobic/Oleophobic Contact Angles**
  - **DI water = 100 - 105°**
  - **Ethylene Glycol = 85-90°**
- **Low Surface Energy**
  - **13-20 dyne/cm<sup>2</sup>**
  - Displays, coatings, paints, leveling, anti-foaming
- **Anti-reflective coatings**
  - **Low refractive index: 1.33 – 1.42**
  - Improve light transmission by reducing the bounce back of light
- **Exterior protection films**
  - Top coatings for display and PV
- **Light guides**
  - Focuses light between two dissimilar materials

# Surface Energy by Contact Angle

- Disruption of liquid molecules on substrate



- G10 KRUSS Contact Angle Measuring System
  - Drop Shape Analysis
- ASTM D7334-08



# Surface Energy Study

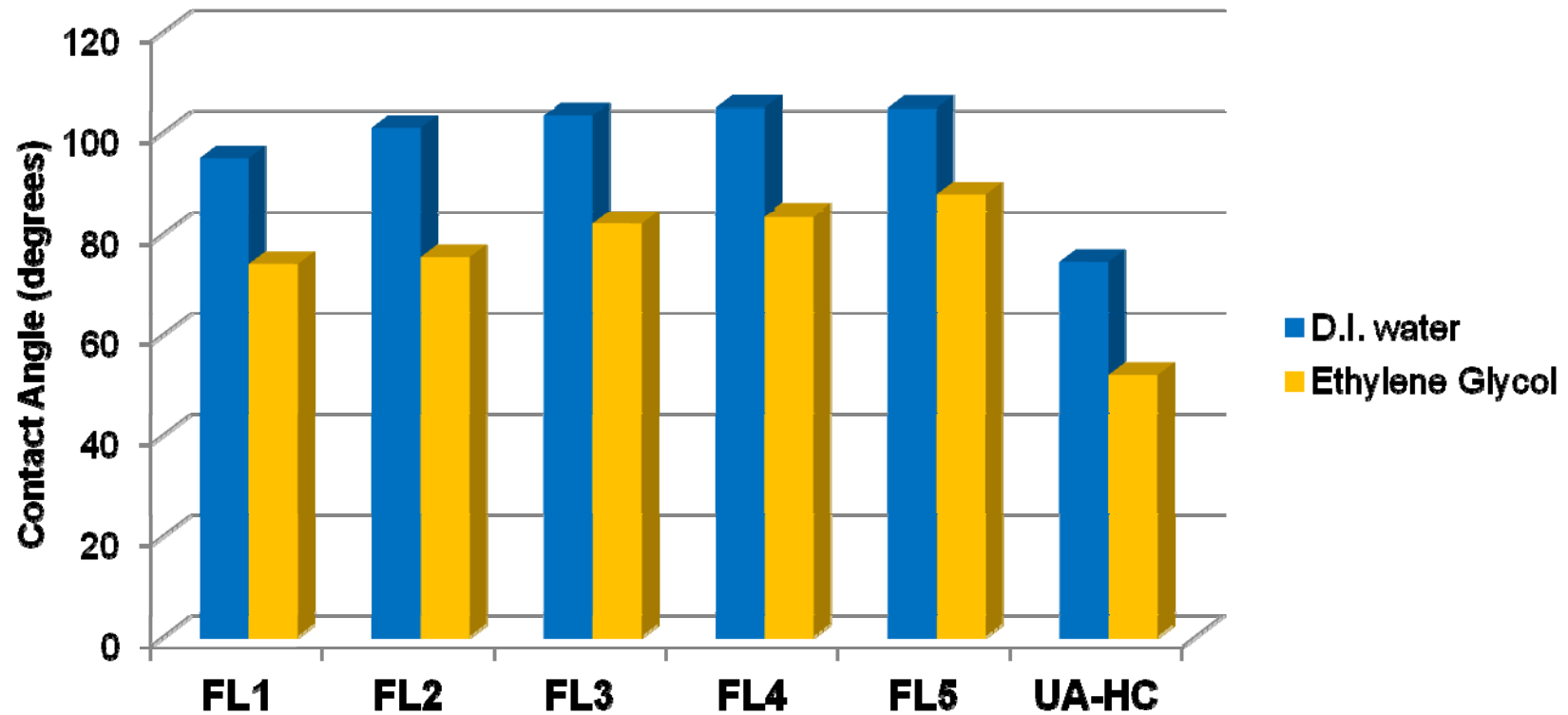
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| Code         | Composition                        |
|--------------|------------------------------------|
| <b>UA-HC</b> | 70%CN9013 + 30% HDDA               |
| <b>FL1</b>   | 70% CN4003 + 30% HDDA              |
| <b>FL2</b>   | 60% CN4003 + 10% CN4001 + 30% HDDA |
| <b>FL3</b>   | 60% CN4003 + 20% CN4001 + 20% HDDA |
| <b>FL4</b>   | 60% CN4003 + 30% CN4001 + 10% HDDA |
| <b>FL5</b>   | 60% CN4003 + 40% CN4001            |

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- UV cured inert atmosphere (no O<sub>2</sub> inhibition)
  - 1 pass 50fpm Fusion F600 type D lamp

# Contact Angle Measurements

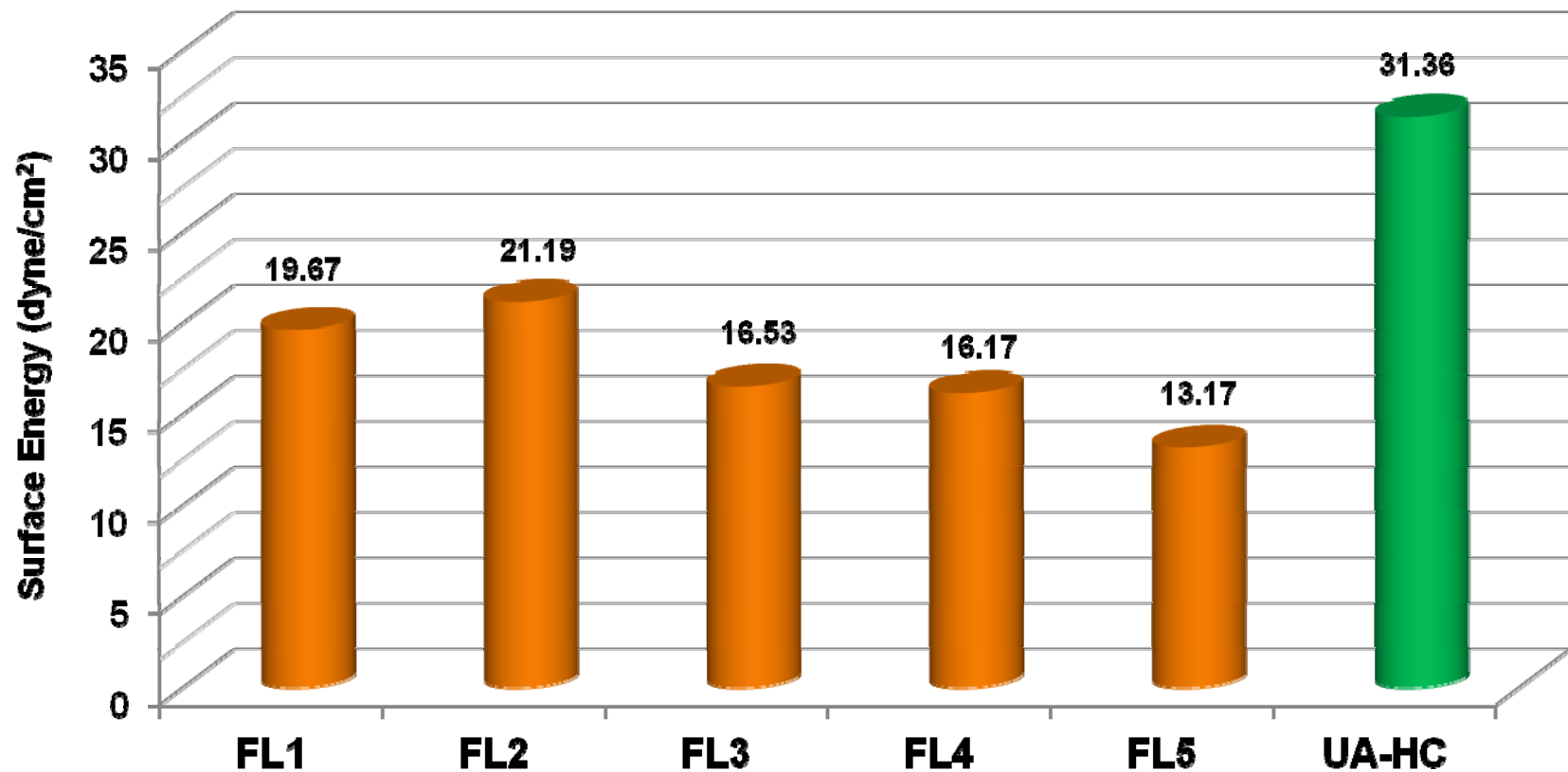


- 90-120° is hydrophobic
- >120° is super hydrophobic
- 70-90° is oleophobic
- >90° is super oleophobic



# Surface Energy of Coatings

- Owen-Wendt-Rabel-Kaelble Calculation



# Refractive Index

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- Measure how much the speed of light is reduced inside a medium
  - $\eta = c/v$ 
    - $c$  : speed of light in air
    - $v$  : speed of light in a medium
- Bending a ray of light when passing through media

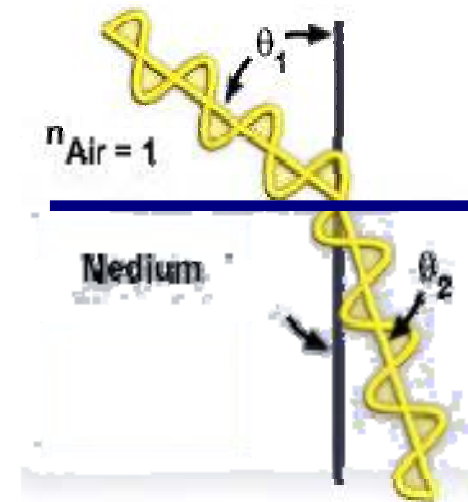
- **Snell-Descartes law** :  $\eta_2 = \eta_1 (\sin\theta_1 / \sin\theta_2)$

$\eta_1 = 1$  , RI of air

$\theta_1$  : incident angle

$\eta_2$  : RI of the medium

$\theta_2$  : refractive angle



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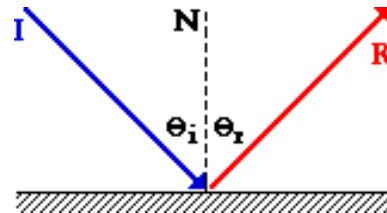
# Common Film Refractive Indices

| Name (abbreviation)                  | $n_D$ (589nm) |
|--------------------------------------|---------------|
| Fluorinated ethylene-propylene (FEP) | 1.347         |
| Cellulose acetate (CA)               | 1.490         |
| Polymethyl methacrylate (PMMA)       | 1.492         |
| Polypropylene (PP)                   | 1.503         |
| Polyisobutylene (PIB)                | 1.508         |
| Polyethylene (PE)                    | 1.514         |
| Crown Glass                          | 1.520         |
| Polyvinylacetate (PCAV)              | 1.529         |
| Polyamide (PA)                       | 1.533         |
| Polyvinylchloride (PVC)              | 1.538         |
| Polycarbonate (PC)                   | 1.585         |
| Polystyrene (PS)                     | 1.589         |
| Polyarylate (PAR)                    | 1.601         |
| Polyethylene terephthlate (PET)      | 1.656         |

# Reflection

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- Law of reflection

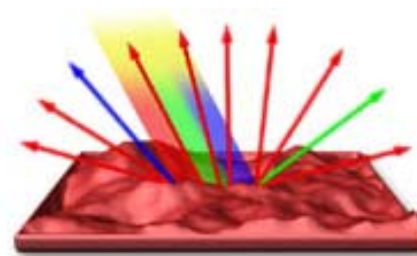


- Types of reflection

- Specular reflection ↔ smooth surface
- Diffuse reflection ↔ rough surface



Specular Reflection



Diffuse Reflection

# Reflectance

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- The % of light reflected at each surface
- $R = (\eta_1 - \eta_2)^2 / (\eta_1 + \eta_2)^2$ 
  - $\eta_1$  : RI of medium 1
  - $\eta_2$  : RI of medium 2
- Universal practice : one medium is air
  - $R = (\eta_1 - 1)^2 / (\eta_1 + 1)^2$

# Reflectance: Air to 1<sup>st</sup> Interface

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- $R = (\eta_1 - 1)^2 / (\eta_1 + 1)^2$

| Medium 1 | $\eta_1$ | Medium 2 | $\eta_2$ | $\Delta$ R.I. | % Reflectance |
|----------|----------|----------|----------|---------------|---------------|
| Air      | 1        | PET      | 1.6560   | 0.656         | <b>6.100%</b> |
| Air      | 1        | PC       | 1.5845   | 0.5845        | <b>5.115%</b> |
| Air      | 1        | Glass    | 1.520    | 0.520         | <b>4.258%</b> |
| Air      | 1        | PMMA     | 1.492    | 0.492         | <b>3.898%</b> |
| Air      | 1        | FL-1     | 1.4146   | 0.4146        | <b>2.948%</b> |

# Reflectance: Coating to Substrate

- $R = (\eta_1 - \eta_2)^2 / (\eta_1 + \eta_2)^2$

| Medium 1 | $\eta_1$ | Medium 2 | $\eta_2$ | $\Delta$ R.I. | % Reflectance  |
|----------|----------|----------|----------|---------------|----------------|
| UA-HC    | 1.516    | PET      | 1.656    | -0.067        | <b>0.195%</b>  |
| UA-HC    | 1.516    | PC       | 1.584    | 0.005         | <b>0.048%</b>  |
| UA-HC    | 1.516    | Glass    | 1.520    | 0.069         | <b>0.0002%</b> |
| UA-HC    | 1.516    | PMMA     | 1.492    | 0.097         | <b>0.0063%</b> |
| FL-1     | 1.415    | PET      | 1.656    | -0.241        | <b>0.618%</b>  |
| FL-1     | 1.415    | PC       | 1.584    | -0.169        | <b>0.319%</b>  |
| FL-1     | 1.415    | Glass    | 1.520    | -0.105        | <b>0.129%</b>  |
| FL-1     | 1.415    | PMMA     | 1.492    | -0.077        | <b>0.071%</b>  |



# Reflectance defines Anti-Reflection

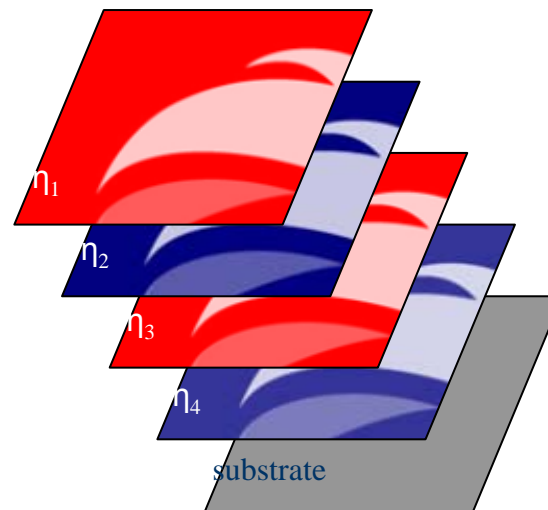
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- Multi-stacked layers
  - Alternating low and high R.I.
- $R = (\eta_1 - \eta_2)^2 / (\eta_1 + \eta_2)^2$
- Direction dependent
- Optimize % of light reflected back to source
- Interference
  - **Positive – add to total light**
  - **Negative – cancel reflected light**

# Anti-reflective coating – Layer Stacking

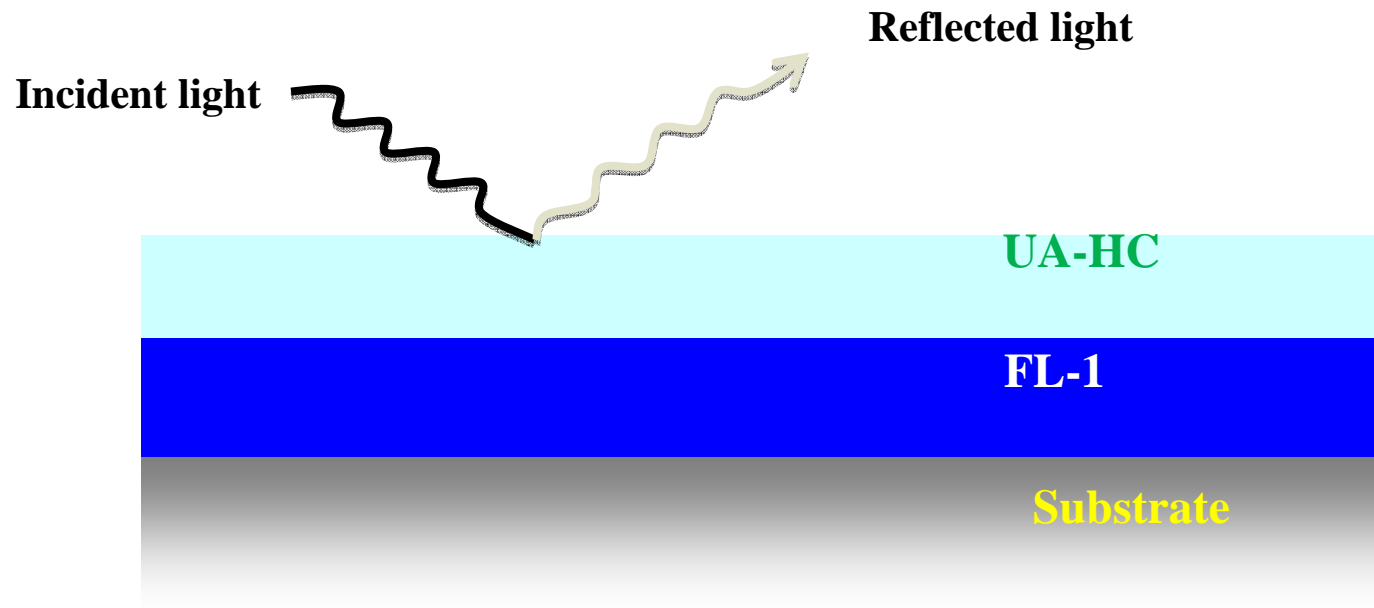
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- $n_1$   $n_2$   $n_3$   $n_4$  substrate A series of layers with different refractive indices can be used to create an anti-reflective coating by means of an index contrast at the interfaces. Every light wave travelling forward through the layers of coating will cancel each other by interference and will produce antireflection.



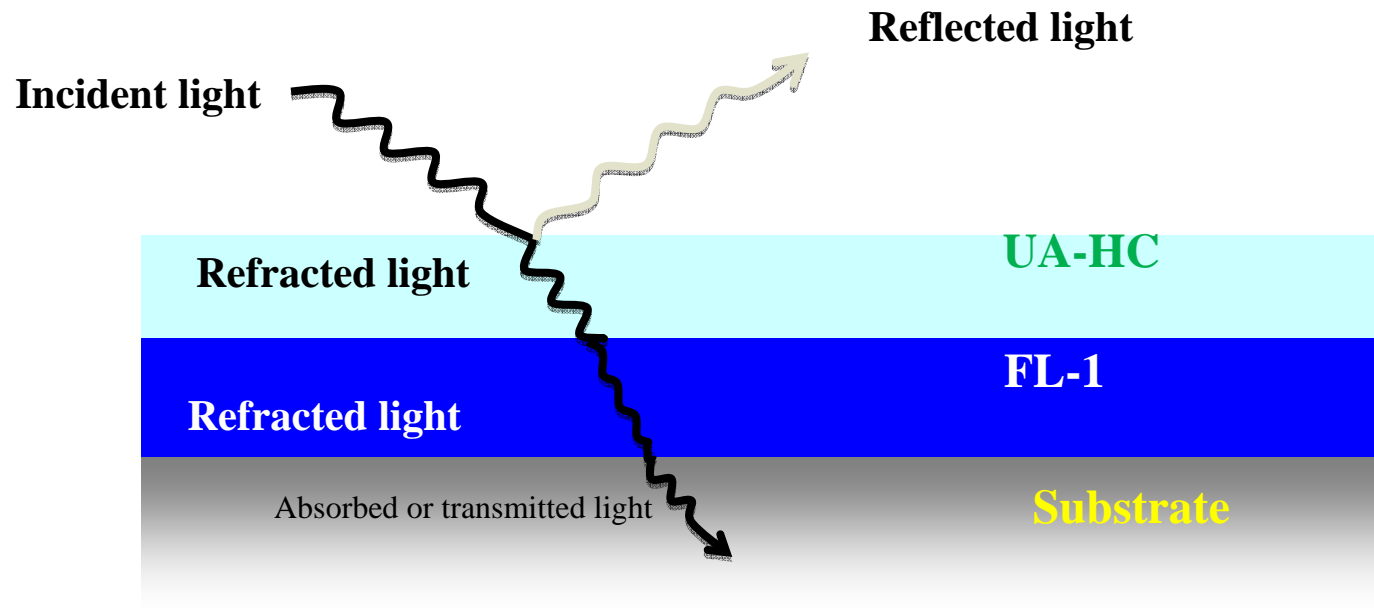
# Anti-reflective coating

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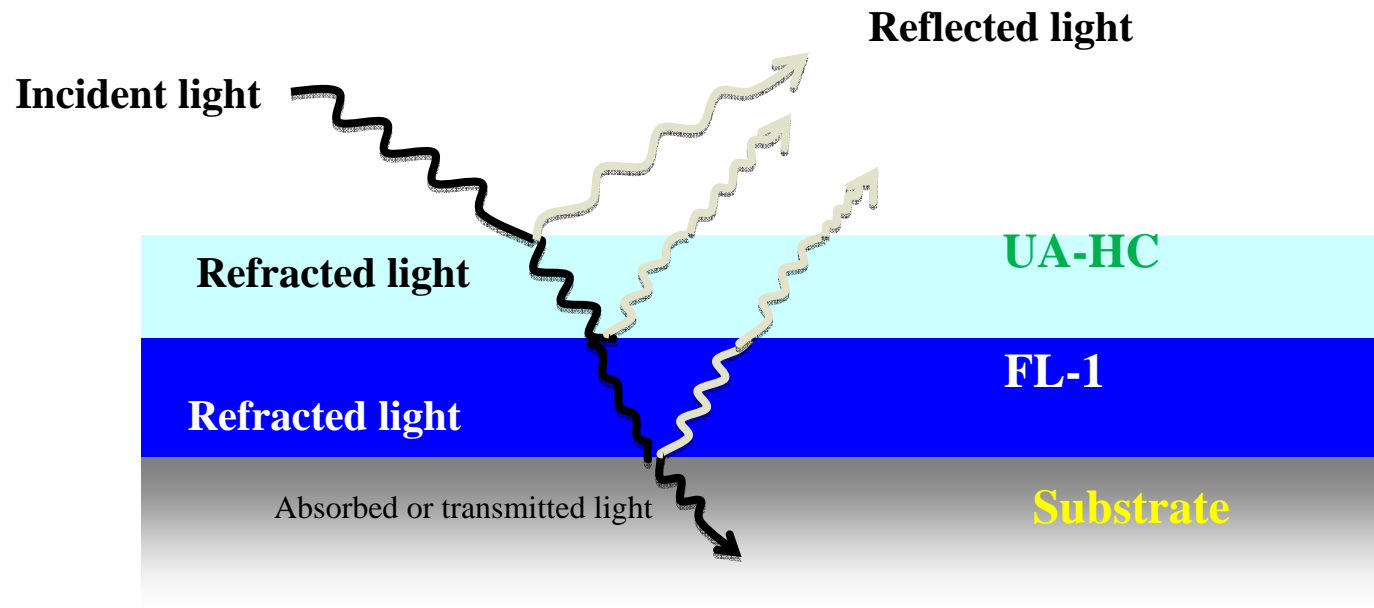
# Anti-reflective coating

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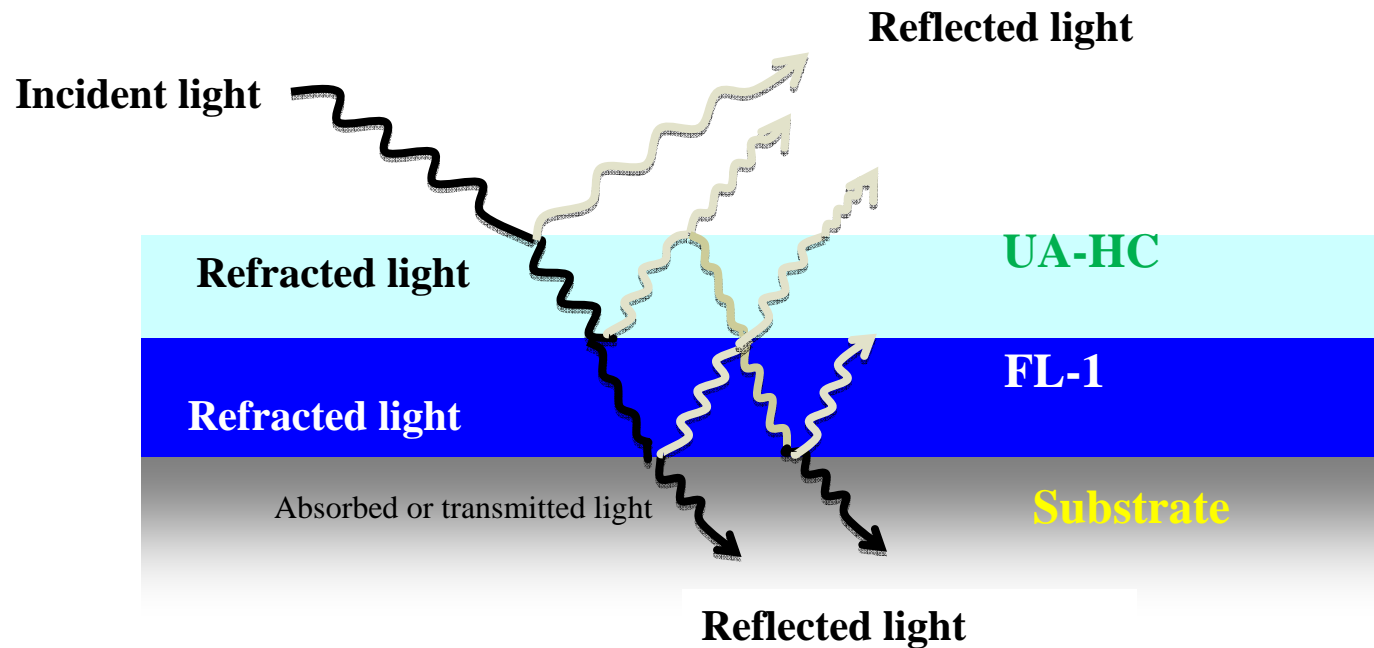
# Anti-reflective coating

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# Anti-reflective coating

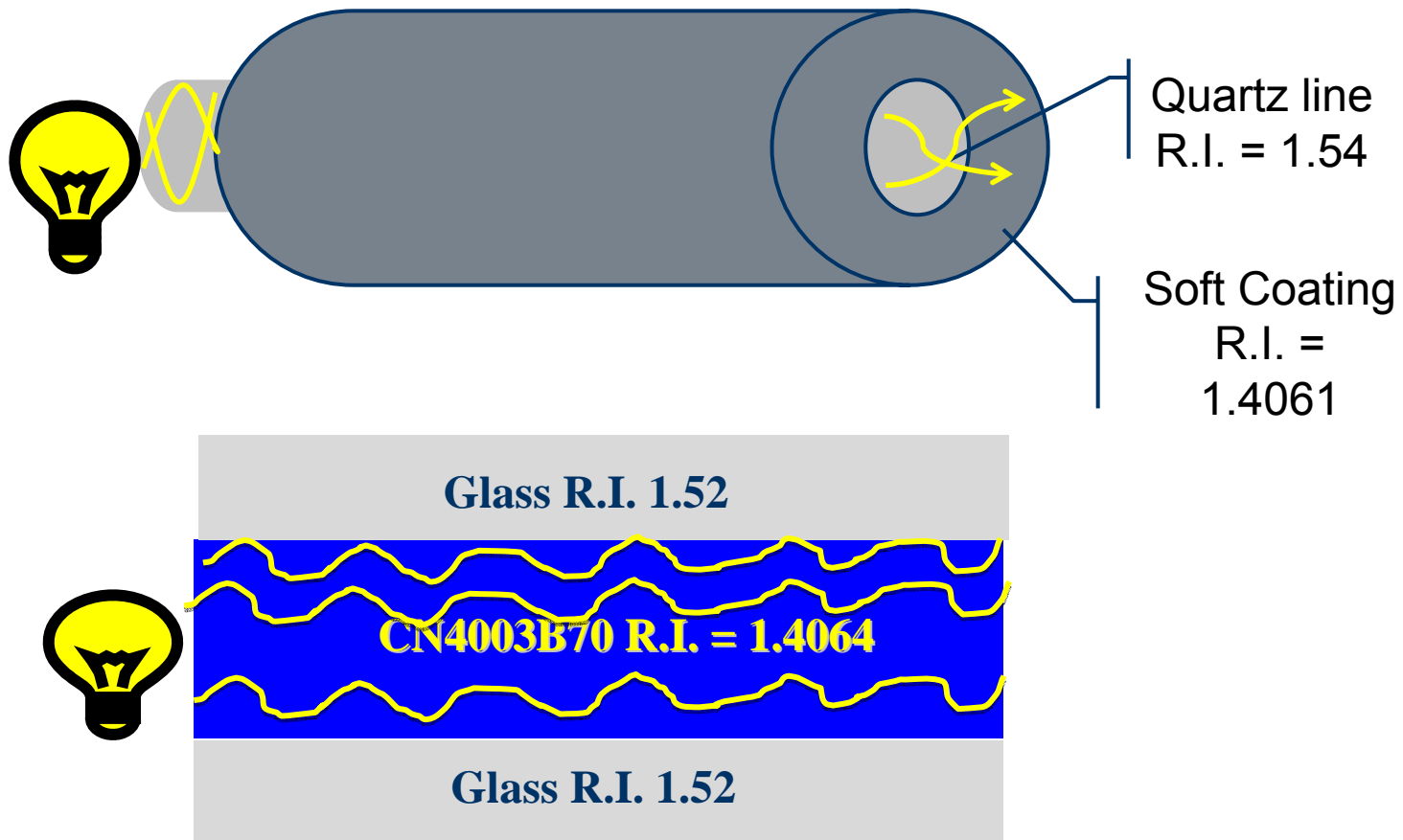
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# Light Guides

Difference in R.I. manages light

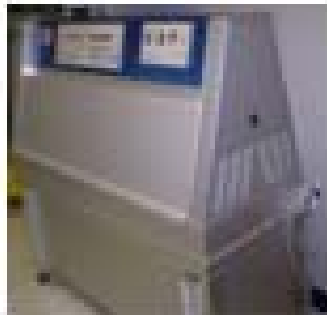
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# Accelerated Weathering - QUV

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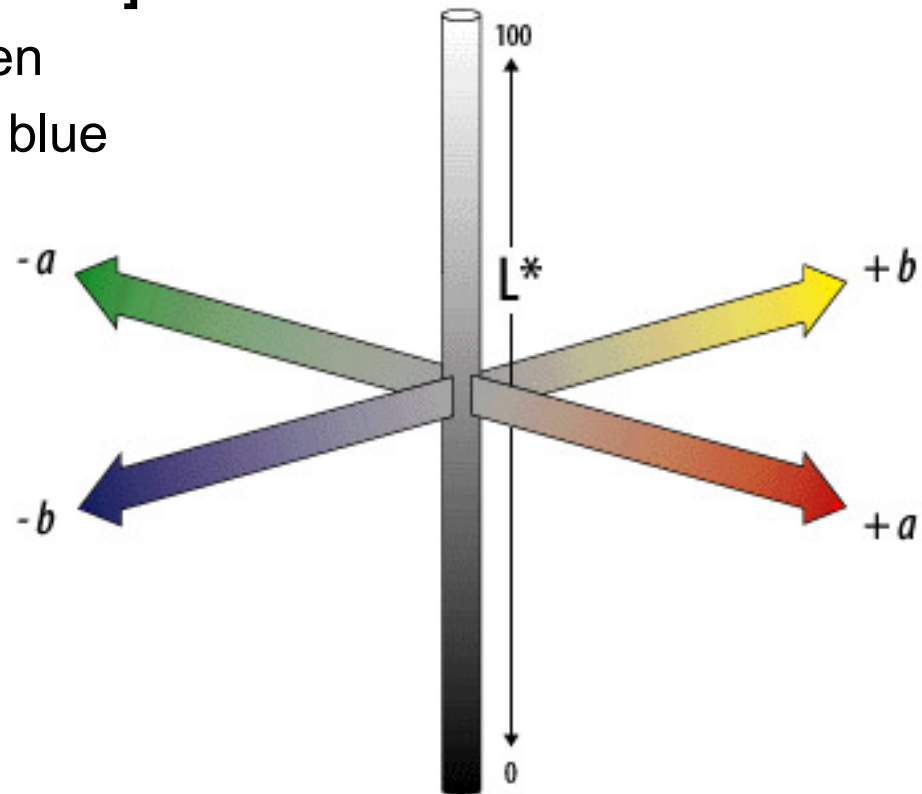
- QUV: ASTM D4329-05 Cycle “B”
  - QUV/Spray equipment
    - Q-Panel Lab Products, Cleveland, Ohio, USA
  - UV “A” lamp 340nm peak irradiance
  - 8 hours 70°C light and UV
  - 4 hours 50°C dark and condensation
  - Cycle “B” = SAEJ2020 for Automotive
  - Cycle “B” technical similar to ISO 4892-3
- FL-1 coated on PET and Polycarbonate





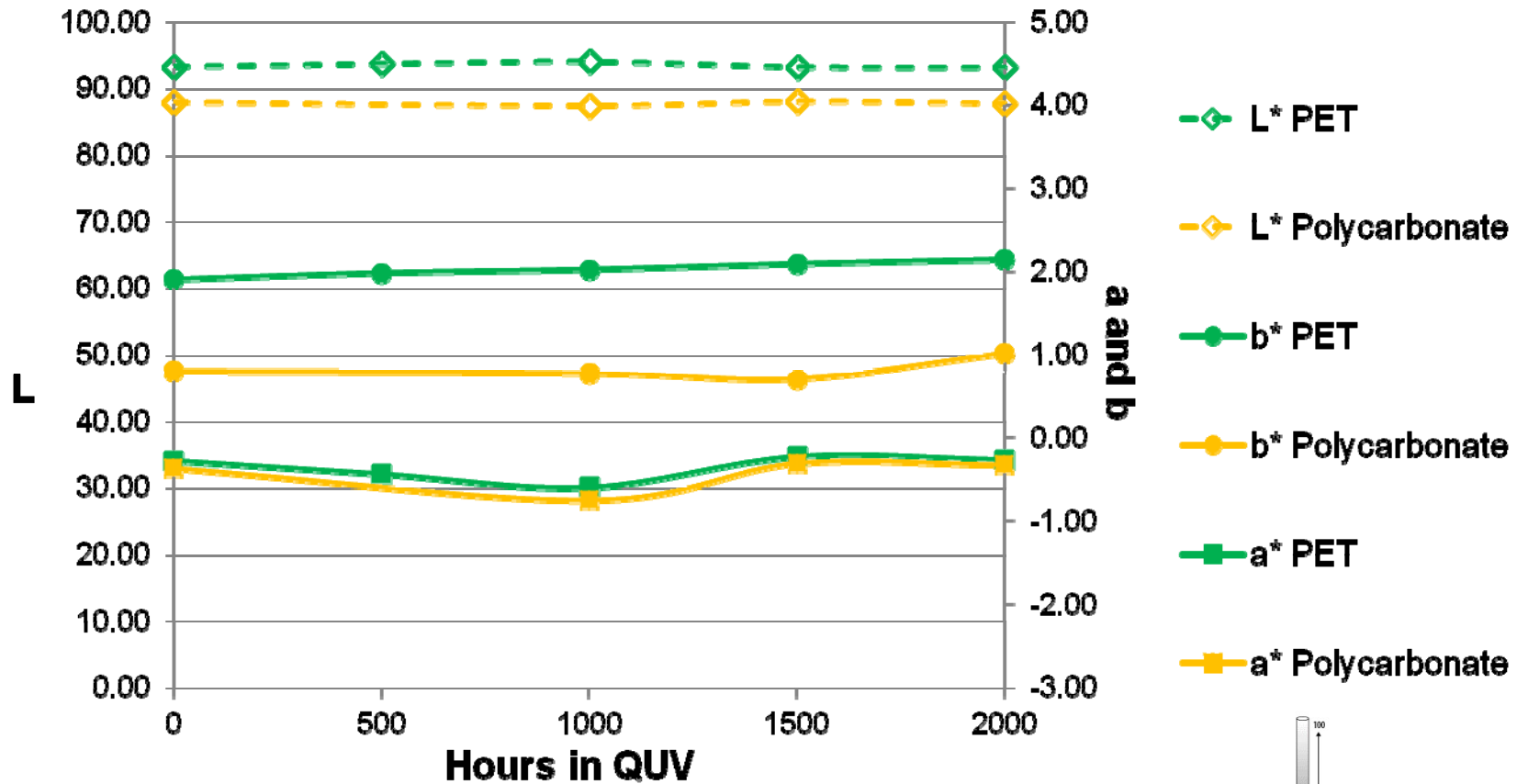
# CIELAB color: ASTM: E308 – 08

- CIE L a\* b\* Color Scale
  - L = 100 perfect reflecting diffuser [white]
  - L = 0 is all absorbing [black]
  - [+] a\* is red, [-] a\* is green
  - [+] b\* is yellow, [-] b\* is blue

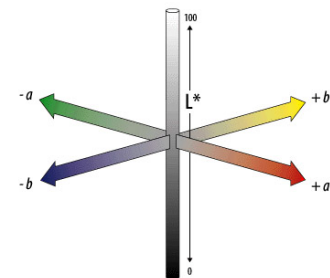


Color guide Sphere d/8 spin  
Cat: 6830 from Byk Gardner  
Columbia, MD 21046

# QUV Fluorinated Weathering Results

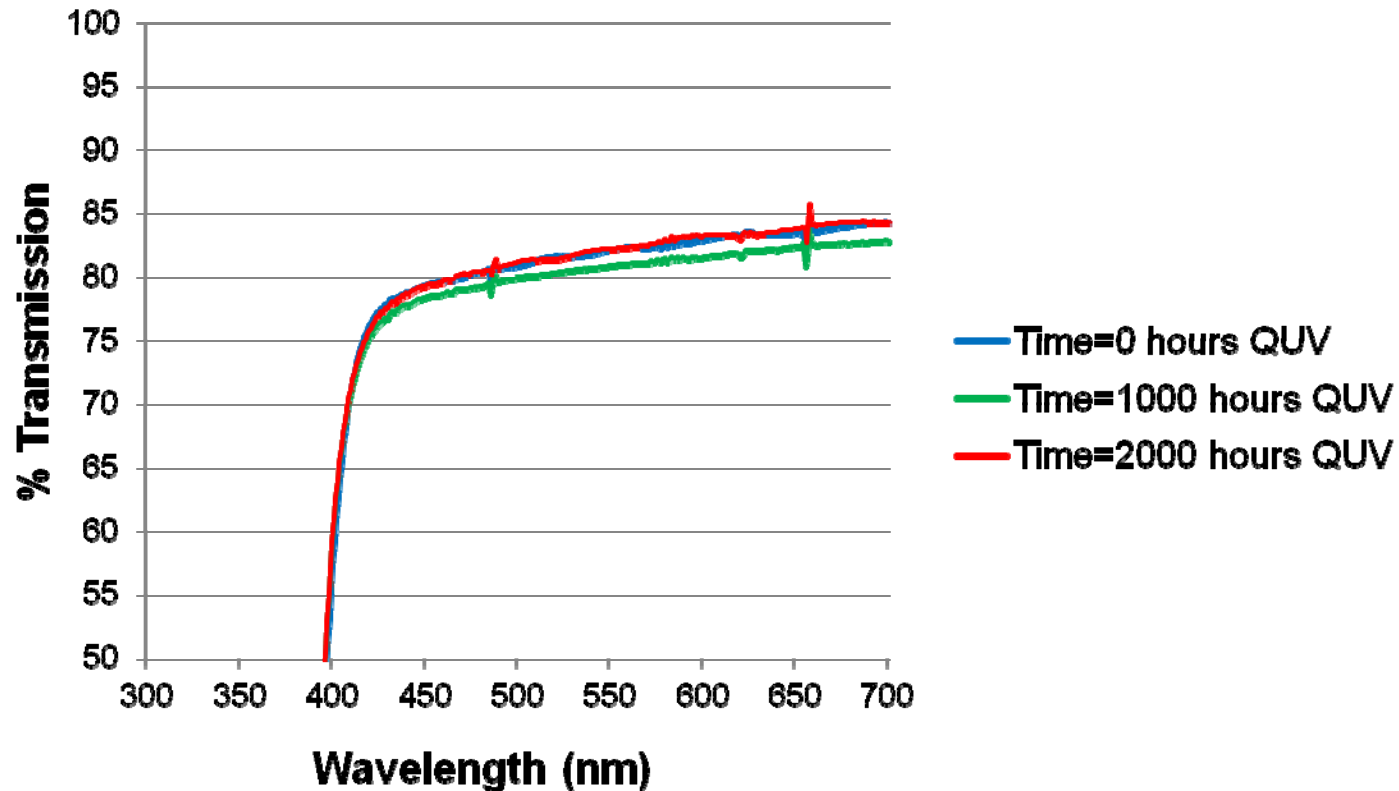


- PET
  - DuPont Teijin Films XST6578
- Polycarbonate
  - 3mm Thick



# QUV PET Exposure

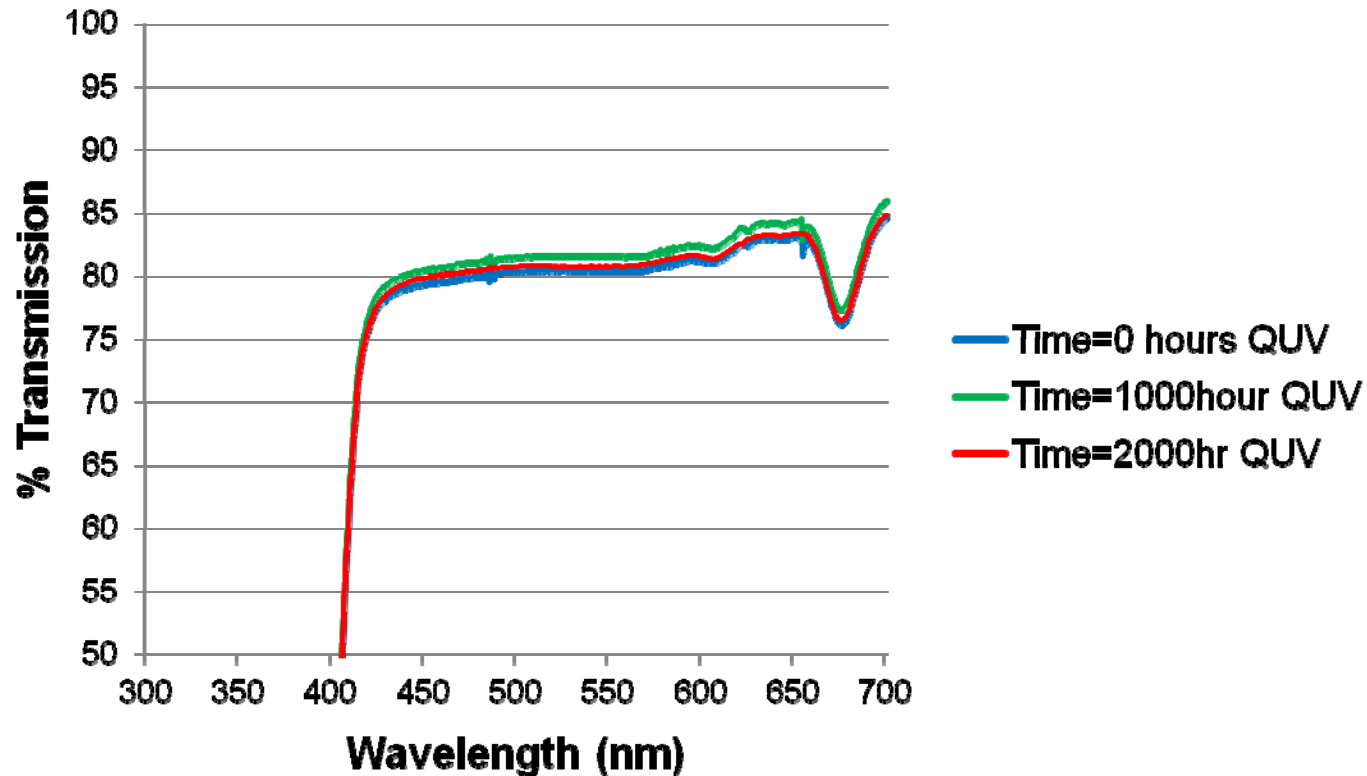
- UV-VIS Spectrophotometer %Transmission



- FL-1 coated on PET
- Agilent 8453 UV-vis Spectrophotometer

# QUV Polycarbonate Exposure

- UV-VIS Spectrophotometer %Transmission



- FL-1 coated on Polycarbonate
- Agilent 8453 UV-vis Spectrophotometer

# Conclusion

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- **Fluorinated Oligomer Advantages**
  - **UV cured polymer coating**
  - Low R.I. for anti-reflective
  - Low surface energy
  - High contact angle
  - Long term exterior weatherability
- **Fluorinated Oligomer Challenges**
  - Selective compatibility with monomers
- **Future Considerations**
  - Achieving higher contact angles
  - Further develop anti-reflective coatings



# Thank you!

Dale Babcock

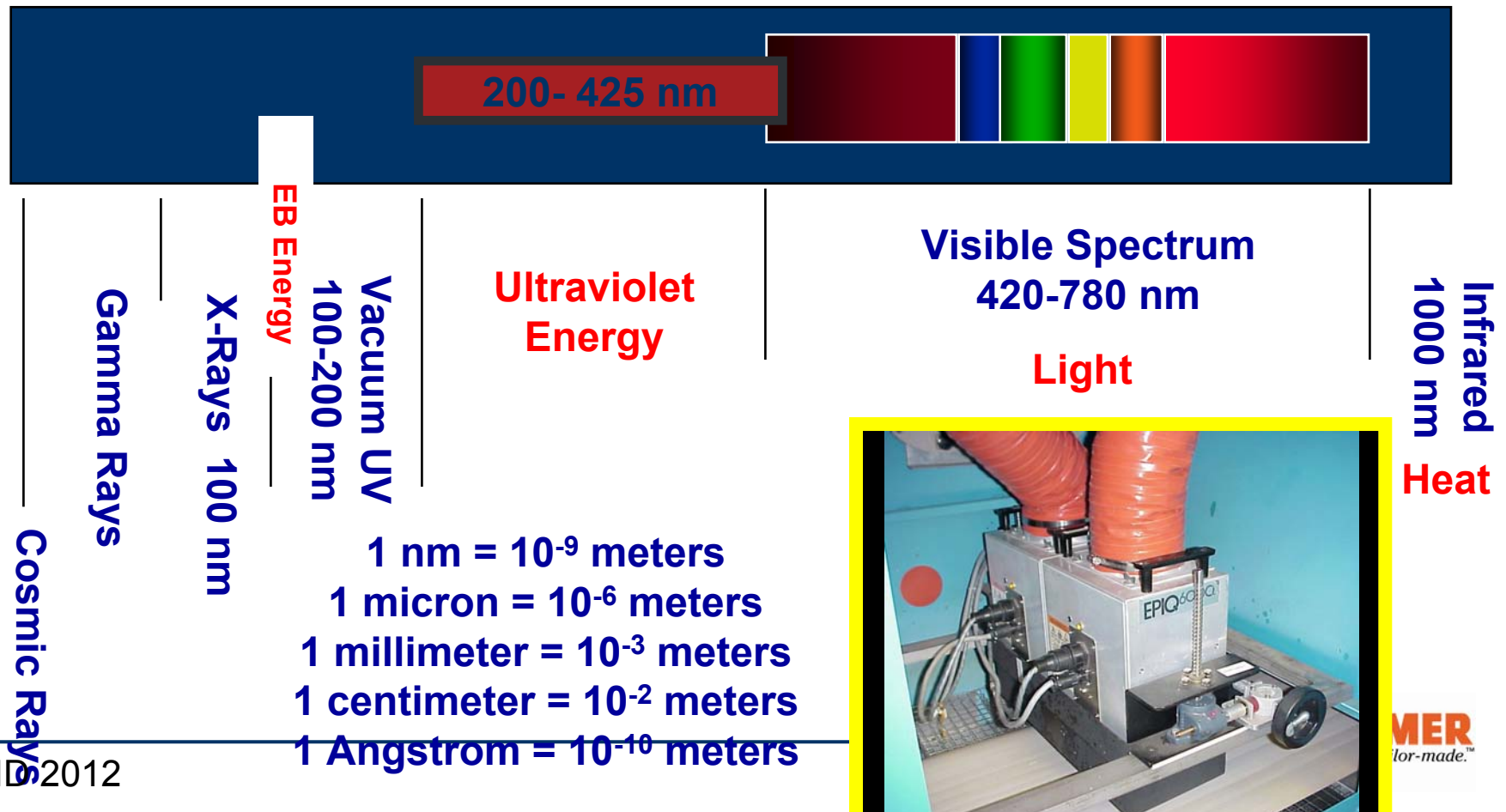
Sartomer – Booth 748

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SID 2012



# The Electromagnetic Spectrum



# “High Refractive Index Properties”

|        | F | Cps<br>25°C | gm/<br>ml | D/cm <sup>2</sup> | R.I.<br>Cured | Tg °C<br>[DMA] |
|--------|---|-------------|-----------|-------------------|---------------|----------------|
| CN2600 | 2 | 164,000     | 1.248     |                   | 1.5985        | 73             |
| CN2601 | 2 | 22,000      | 1.216     |                   | 1.5902        | 58             |
| CN2602 | 2 | 147,800     | 1.178     |                   | 1.5760        | 68             |
| CN2603 | 2 | 3,600       | 1.136     |                   | 1.5723        | 78             |
| CN2604 | 2 | 11,600      | 1.122     |                   | 1.5620        | 43             |
| CN2605 | 1 | 250         | 1.211     |                   | 1.5403        | 37             |
| CD590  | 1 | 55          | 1.112     | 38.7              | 1.5601        | 12             |
| SR349  | 2 | 1,480       | 1.119     | 41.3              | 1.5589        | 67             |
| SR348  | 2 | 1,082       | 1.119     | 41.0              | 1.5573        | 102            |
| SR339A | 1 | 12          | 1.103     | 39.2              | 1.5345        | 5              |
| CD833S | 2 | 130         | 1.108     | 36.0              | 1.5163        | 144            |



# Oligomer diluted with CN4001

CN4003 completely soluble

| % CN4003         | 90     | 80     | 60     | 50     | 30     | 20     | 10      | 0       |
|------------------|--------|--------|--------|--------|--------|--------|---------|---------|
| CN4001           | 10     | 20     | 40     | 50     | 70     | 80     | 90      | 100     |
| Cps @25C         |        |        | 78,000 | 6,000  | 1,500  | 535    | 240     | 100     |
| Liq RI @ 589nm   | 1.3903 | 1.3872 | 1.3772 | 1.3590 | 1.3573 | 1.3539 | 1.3482  | 1.3428  |
| Cured RI @ 589nm | 1.4029 | 1.3902 | 1.3810 | 1.3621 | 1.3611 | 1.3598 | 1.3532  | 1.3479  |
| Pencil Hardness  |        | 2H     | 1H     | 1H     | 1H     | 1H     | 1H      | 1H      |
| Pencil Hardness  |        | 2H     | 1H     | 1H     | 1H     | 1H     | 1H      | 1H      |
| Surface Cure     | Good   | Good   | Good   | Good   | Good   | Good   | Scratch | Scratch |

# Light in UV Coating Applications

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- Light Transmission and UV Energy Transmission
  - Percent of light at various color spectrums
  - Color vs. Wavelength
    - Refractive Index
    - ABBE Number
  - Reflection / Reflectance
    - Determines the % of light reflected at each surface
  - Weathering
    - L a b and Y x y Color scale
    - % Transmission