

3M Film Materials

Corporate Research Process Lab
Specialty Films Group

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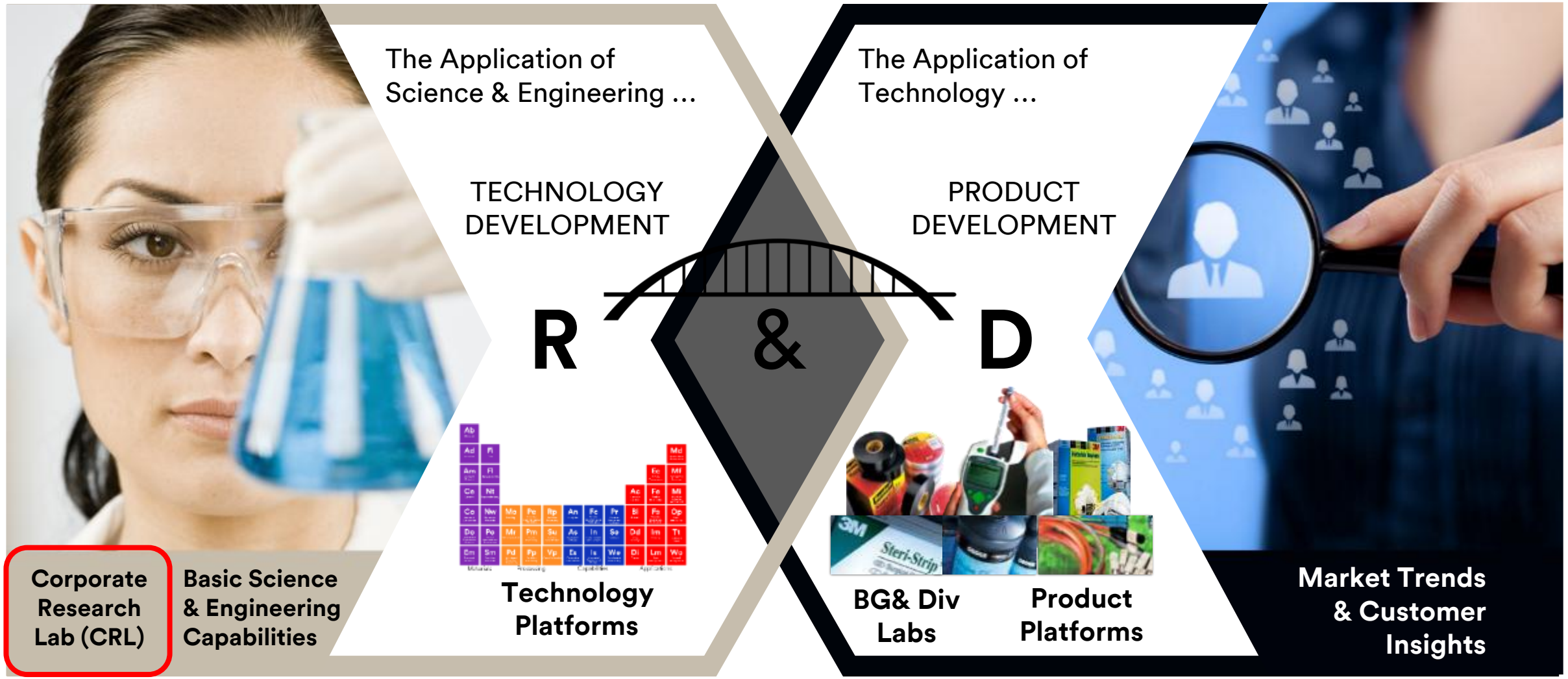
3M operates an integrated innovation model

Creation and application of technology to product development



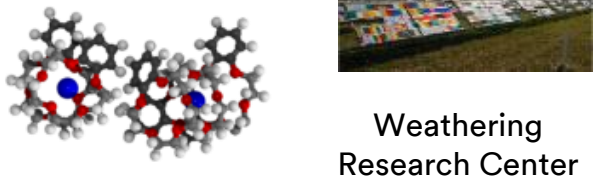
Commercialization through different go-to-market models: Consumer + Industrial + OEM Spec-in

CRL Integrates Analytical, Materials, Process, and Systems

Corporate Research Analytical Laboratory (CRAL)

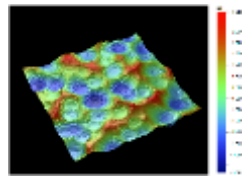
Growth through fundamental scientific understanding & data analytics

Molecular Analysis



Weathering Research Center

Materials Characterization



Imaging & Surface Analysis

Intellectual Property Substantiation

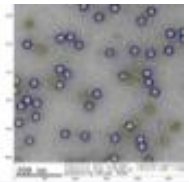
gALAxy Analytical Lab Analytics

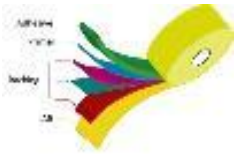
Analytical Analytics

Corporate Research Materials Laboratory (CRML)

Creating new materials that provide a sustainable competitive advantage

BioSciences



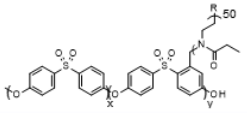


Adhesives & Release Materials

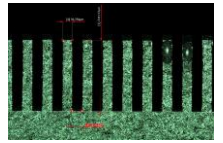
Optical / 5G

Ceramics & Glasses

Specialty Materials



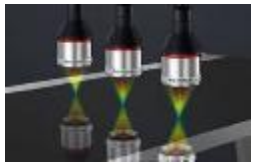
Films, fibers, coatings



Emerging Energy

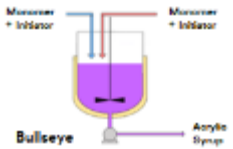
Corporate Research Process Laboratory (CRPL)

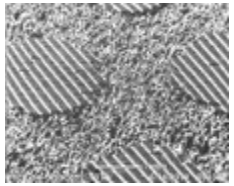
Building new, differentiated process and manufacturing platforms



Digital Manufacturing, Analytics & Processing

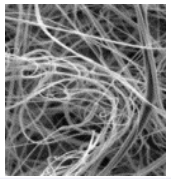
Materials & Radiation Processing

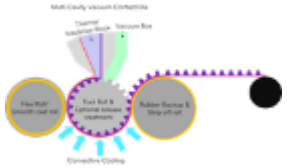




Precision Coating & Web Processing

Nonwovens, Membranes & Ultrasonics

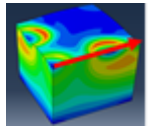




Specialty Films, Microreplication & Polymer Processing

Corporate Research Systems Laboratory (CRSL)

Building integrated systems and digital platforms to enable new products



Modeling & Simulation

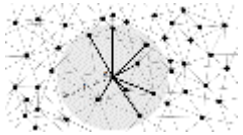
Software Technology, Machine Learning, & Data Science

Data Systems

Advanced Integrated Systems

AMX /Extreme Mechanics

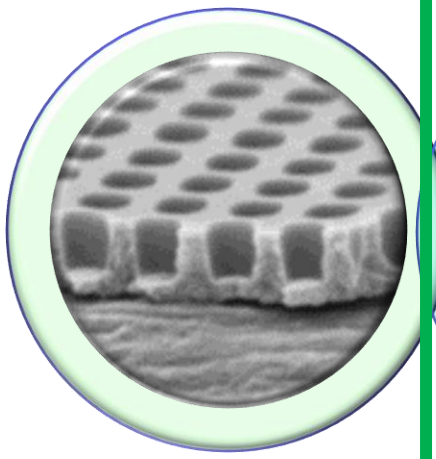
Materials Informatics



Four interconnected labs organized around technology "clusters" that are leveraged across 3M

Corporate Research Process Laboratory

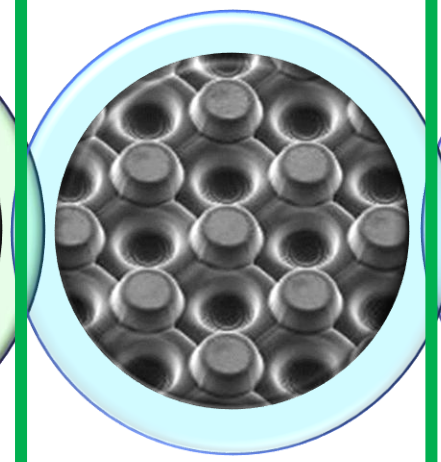
Precision Coating & Web Processing
PCWP



Technologies

- Coating
- Drying
- Printing & Patterning
- Optical Metamaterials
- Process Mechanics
- Embedded Modeling

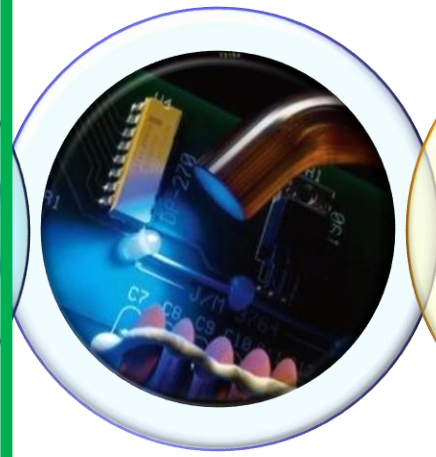
Specialty Films, Microreplication & Polymer Processing
SFMPP



Technologies

- Hot Melt Coating
- Reactive Extrusion
- Blown Film
- Oriented Film
- Extrusion Replication
- Continuous, Cast & Cure

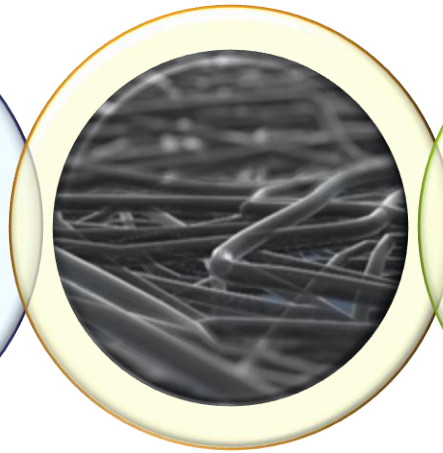
Materials & Radiation Processing
MRP



Technologies

- Chemical Processing
- Radiation Processing
- Plasma & Surface Modification
- Thin Films
- Ceramics & Particle Processing

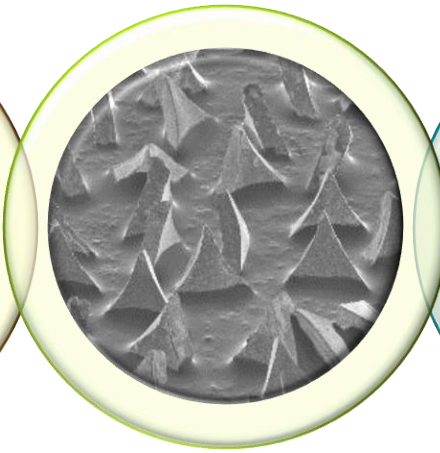
Nonwovens, Separations & Ultrasonics
NWSU



Technologies

- Melt Blown
- Spunbond
- Fiber Processing
- Separations Technologies
- Modeling & Informatics
- Ultrasonics

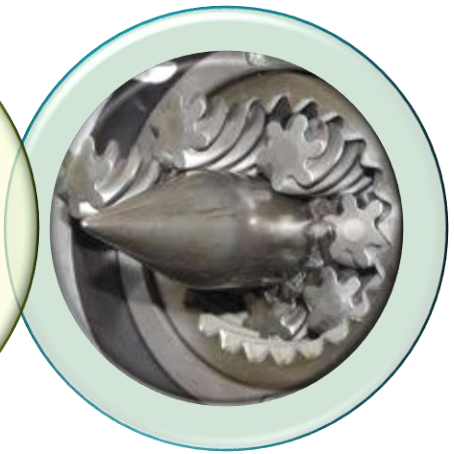
Digital Manufacturing Analytics & Processing
DMAP



Technologies

- High Resolution Additive Manufacturing
- Rapid Prototyping
- Injection Molding
- Measurement & Process Analytics
- Robotics & Automation
- Process Informatics

CRPL
EMEA



Technologies

- Euro Express Line
- Hotmelt, Film, Multilayer & Co-Extrusion
- Liquid Coating
- PSA Process Tech
- Reactive Extrusion
- Hotmelt Compounding
- Injection Molding

Aligned to 35+ Technology Platforms

CRPL Extrusion Lines

1-Feed

Powder

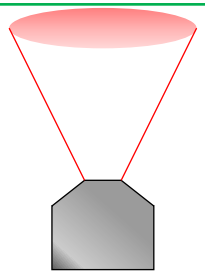
Liquid

Pellet

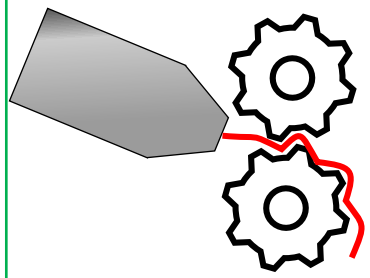
2-Melt/Mix

3-Meter

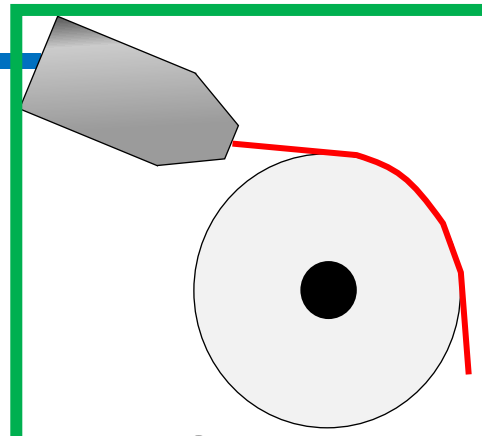
4-Shape/ Quench



Blown-2

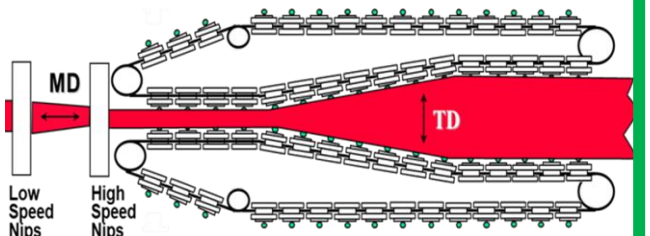


Replicated-3

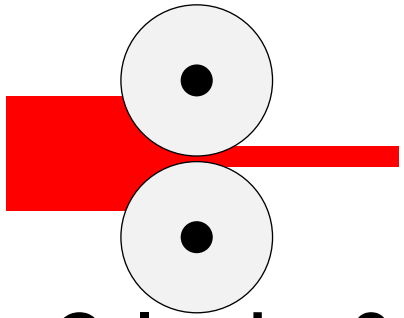


Cast-7

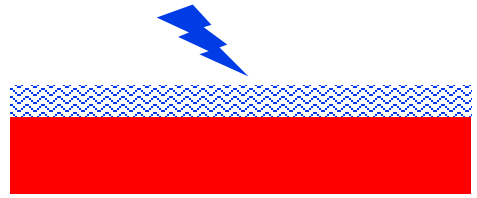
5-Post Process



Stretch-1



Calendar-2



Functionalize-4

3M

3M Oriented Film Development to Manufacturing

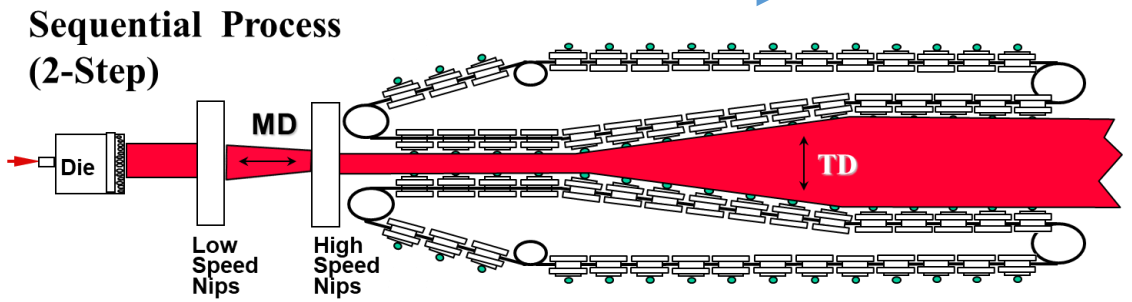
CRPL
- Casting only
- 1-50 lb/hr
- 2-18” wide film
- Up to 5 layers
- Best for material screening

CRPL
- Biaxial stretching
- 25 – 200 lb/hr
- 8-30” wide films
- Up to 13 layers
- Limited production

3M Manufacturing
- Biaxial stretching
- 300-10,000+ lb/hr
- 50-240” wide film
- 1-1000 layers
- PP, PET, MOF, etc.

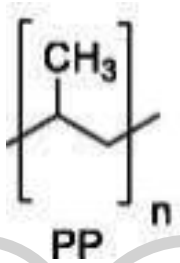
Lab Scale → **Pilot Scale** → **Production Scale**

Strategically sized equipment at multiple scales to enable new product development



10+ Lines, 8-240”

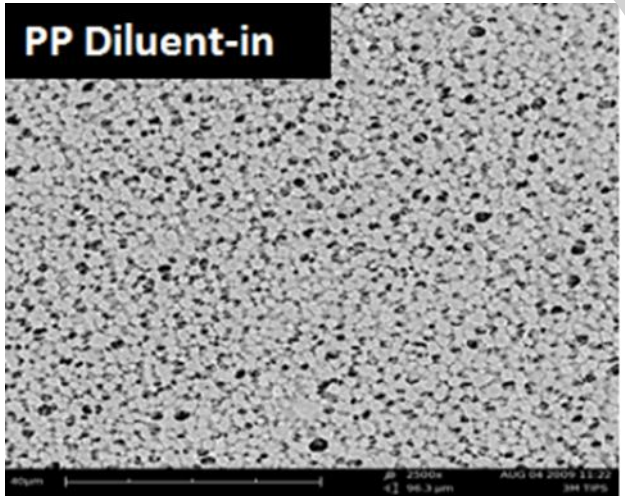
3M Polypropylene Films



Lint Roller Tape - Cast

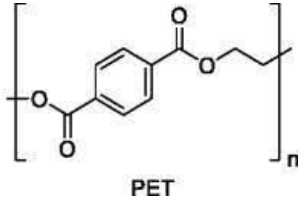
Dual-Lock - Replicated

Box Sealing Tape – Biaxially Oriented



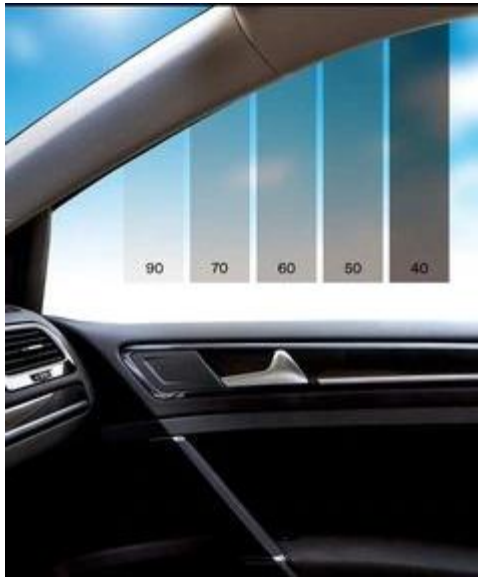
Porous Films – Biaxially Oriented

Polyethylene terephthalate Film



PET

3M Light Control Films



3M Safety and Security Window Films

3M Science. Applied to Life.™

Safety & Security Building Window Film Portfolio

Commercial Buildings

Thicker films

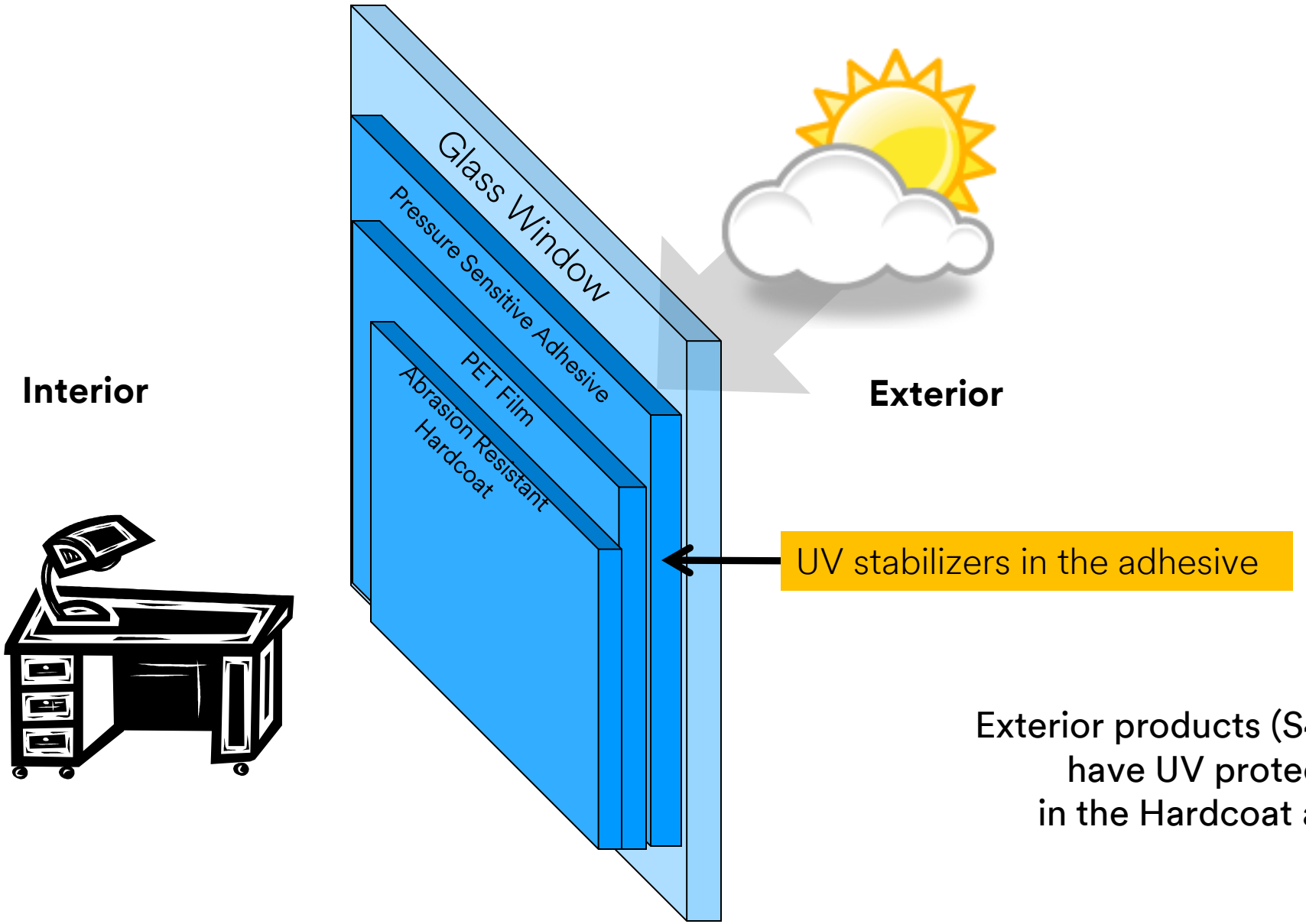
Thicker adhesive

Tear resistant properties

Tested to an industry standard for “safety” glazing

Provide impact resistance and glass fragment retention properties

Window Film Basic Construction

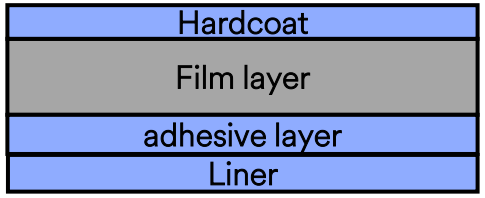


Exterior products (S40X, S70X)
have UV protection
in the Hardcoat as well.

Film Constructions

Monolithic = single layer of film

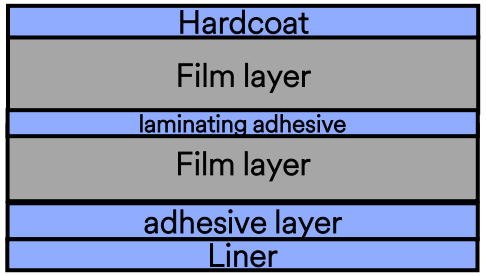
- Safety S40, S70, S40X, S70X



Monolithic

Laminated = 2 or more layers of film

- Safety S80
- Safety S140
- AG6
- Safety Series with Sun Control

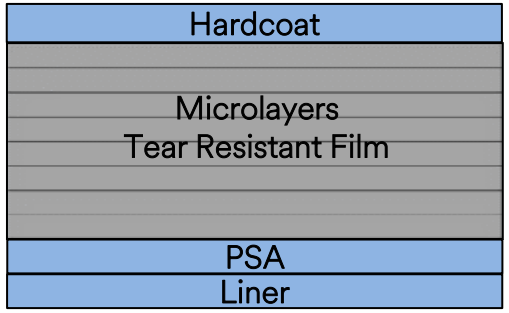


Laminated

Ultra Films = microlayered film construction

- Unique to 3M, produced during film extrusion process, not through lamination
- Ultra S800
- Microlayered film may be laminated to other film

  –*Ultra Prestige S50, Ultra Prestige S70, Ultra Night Vision S25*



Microlayered

Testing for Tear Resistance

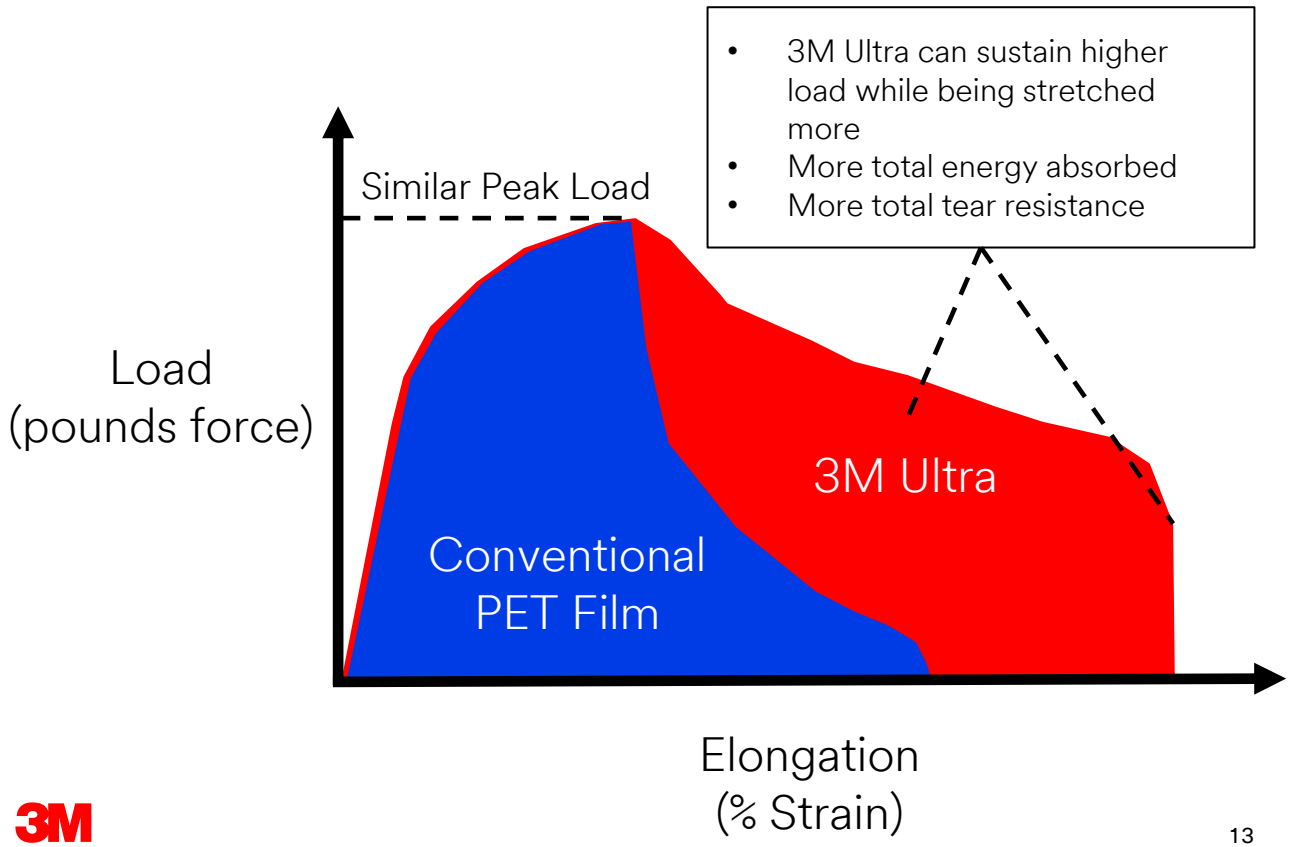
Peak Load

- Mostly a function of film thickness
- Conventional films will have similar peak load as Ultra films

Elongation

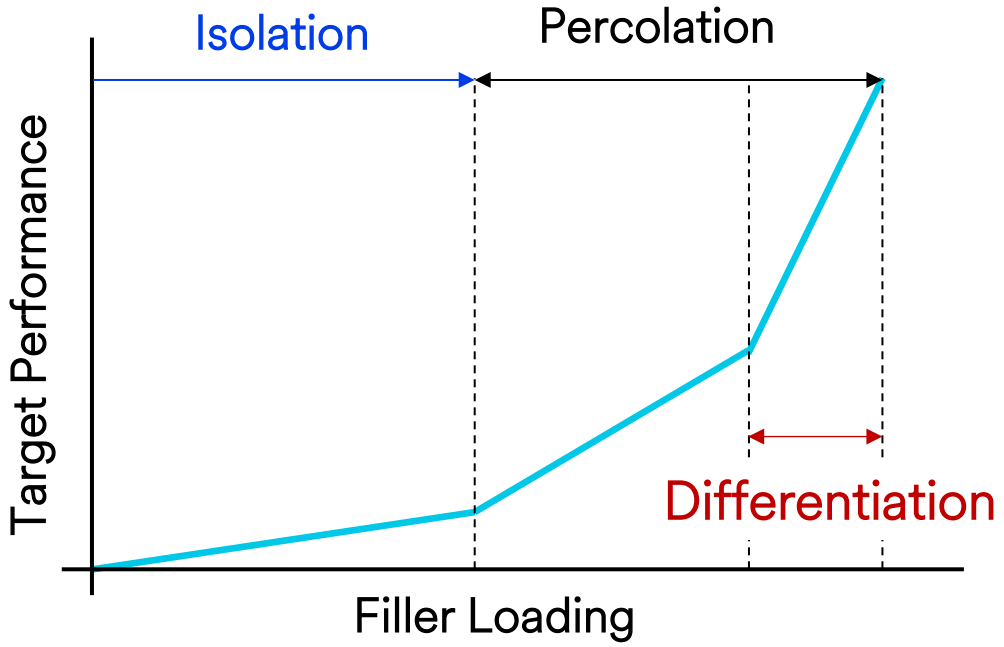
- Ultra will stretch more than conventional films
- More energy absorption before failure

Example Graves Tear (ASTM D1004)
Resistance Plot:
Conventional PET vs. Ultra (same thickness)




3M Advanced Composite
Processing

3M Particle Loaded Composites



Engineered Materials

Acrylic hotmelts	Multi-modal filler packages
UV xlinking system	Alumina Trihydrate (ATH)
Glass-bubbles	Tungsten-coated alumina
UHMWPE	3M Hexagonal BN (h-BN)

+

Processes

Extrusion	Coating
Film casting	Compounding
Densification	Dispensing
Crosslinking/Curing	Stacking/Skiving

=

Differentiation

Particle Loading	Balanced Properties
Porosity Control	Particle Alignment

Thermal Interface Material Tech Data Sheet (New Concept)

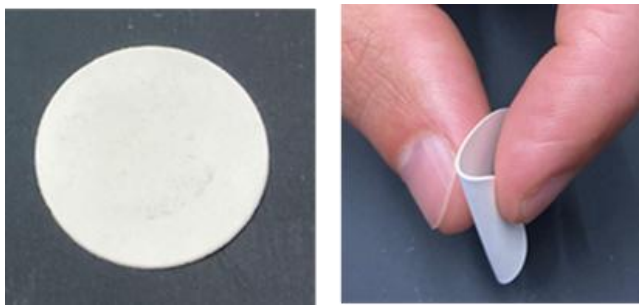
Thermoplastic thermally conductive pad

Product Description: A tunable film based electrically insulating, silicone free TIM material with exceptional thermal performance.

Technology: Ceramic / polyolefin / elastomer

Application: Thermal Management, TIM Thermal Interface Material

Flexibility:



Features

- Anisotropy tunable to xy or z
- Porosity control for hardness & dielectric properties
- Geometry options possible
- Optional EMI absorber
- No volatiles
- Ceramic particle
- Film, easy removability, rework

Tunable properties: Anisotropic properties offer design freedom.

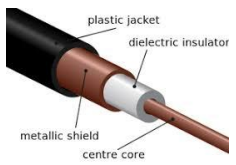
Property	Heat spreader pad	Z-axis pad
Through plane thermal conductivity (anisotropic)	**2 to 8** (W/mK) anisotropic	**20 to 45** (W/mK) anisotropic
In-plane thermal conductivity (anisotropic)	**20 to 60** (W/mK) anisotropic	**2 to 8** (W/mK) anisotropic
D_K @ 5.1 GHz	**2 to 4**	**2 to 4**
D_F @ 5.1 GHz	**0.001 to 0.0002**	**0.001to 0.0002**
Hardness	**70 Shore 0 to 92 Shore A**	**70 Shore 0 to 92 Shore A**
Electrically insulating (ASTM D257)	**$1.8*10^{13}$ Ωm**	**$1.8*10^{13}$ Ωm**
Breakdown strength (ASTM D149)	**> 5 (kV/mm)**	**> 5 (kV/mm)**
Thickness range	**0.1-1 mm**	**0.1-1 mm**
Color	**~white opaque**	**~white opaque**
Density	**1.5 to 2.1 (g/cc)**	**1.5 to 2.1 (g/cc)**
Heat Capacity	**0.7 to 0.9 (J/gK)**	**0.7 to 0.9 (J/gK)**
Upper service temperature	**~225 °C**	**~225 °C**
Form	**Rolls & sheets, silicone free, halogen-free**	**Sheets , silicone free, halogen-free**

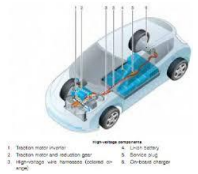
Dielectric Development

Aluminum and Aluminum Oxide coated S60 Glass Bubbles

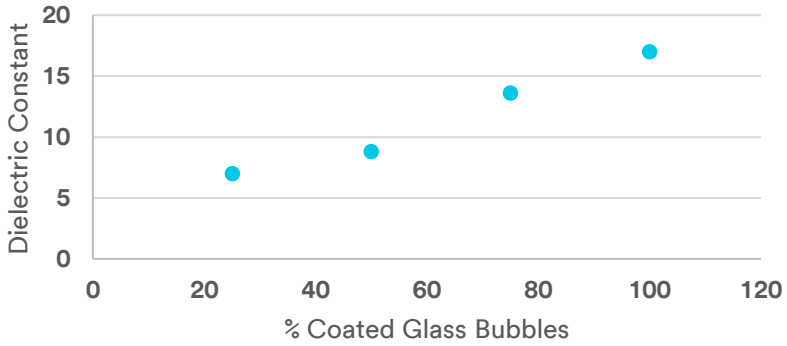
Applications:

- Electric field insulators (displays, transformers, electric vehicles)
- High dielectric constant cable accessories
- Microwave lenses and antennas
- Electromagnetic radiation absorbers (radar and electronic shielding)
- Low dielectric insulators/radome



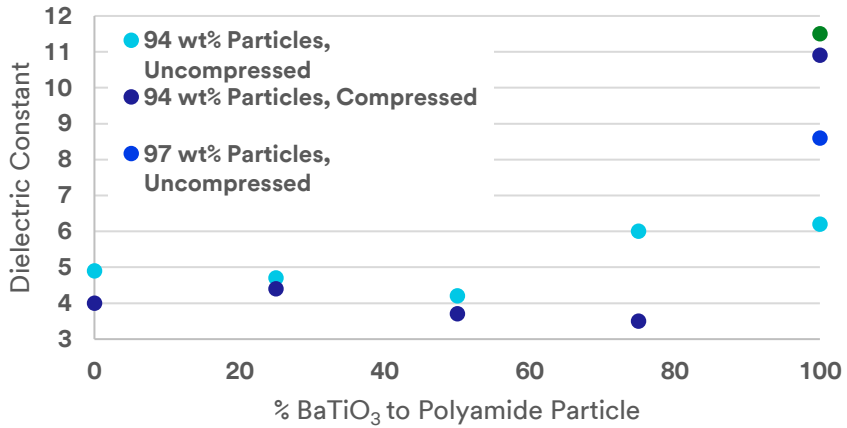


Mixture Coated and Non-coated Glass Bubbles



Demonstrated tunable dielectric constants not accessible by existing methods

Mixture Dielectric and Non-dielectric Particles and Particle Loading



3M™ Electronic Assembly Solutions Portfolio Offering

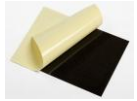
Electromagnetic Interference (EMI) Solutions

Tapes

Absorbers

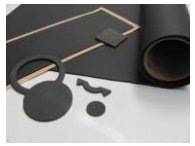
Magnetic Isolators

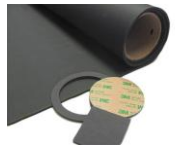
Foam Gaskets



ACF

ISOLOSS™ LS Polyurethane Foams





Aearo Technologies LLC

Water Contact Indicator Tape

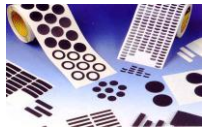
Thermal Interface Materials

Tapes

Adhesives

Grease

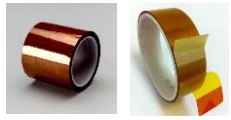
Bumpon™ Protective Products



Low Outgassing Label Material

High Temperature Masking

Low Static Polyimide Tapes



PCB Plating Tapes

Polyester Tape

Thermal Bonding Films

3M™ EMI/RFI Management Solutions

EMI Shielding & Grounding

- **Grounding** creates an electrical connection between metal parts to help protect circuitry from electrostatic discharge (ESD).
- **Shielding** blocks/reflects harmful electromagnetic waves to help reduce EMI noise.

3M Solutions:

3M™ Electrically Conductive Tapes
3M™ Transparent Conductor Films
3M™ Electrically Conductive Gasket Tapes

Foil and fabric conductive tapes

EMI Absorbing & Magnetic Shielding

- **Absorbing** EMI converts the energy to heat (an insignificant amount), so less EMI is reflected to affect other nearby components.
- **3M™ Magnetic Shielding Materials** help protect sensitive electronic components and circuitry by shielding external low magnetic fields (<1MHz).

3M Solutions:

3M™ EMI Absorbers
3M™ Magnetic Shielding Materials

Absorbers = high frequencies

Magnetic Shielding Materials = EM field less than 15 MHz

Stratospheric and low earth orbit (LEO) platforms for global persistent communication and imaging

There is a need for global, dynamic, persistent telecommunications and monitoring capabilities

Pierre Markuse CC-BY-2.0

Support Forces of Ukraine Command CC-BY-4.0

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High altitude long endurance (HALE) unmanned aerial vehicles (UAVs) & LEO satellites

Provide platforms for needed telecom and monitoring

Designed for efficiency. Built to last.

Flexible solar solutions from 3M™

3M™ Ultra Barrier Films and Charge-Collection Tapes provide innovative and durable solutions for flexible solar modules used in various applications, including automotive, consumer electronics, rooftop and other building-integrated PV applications. Our solar tapes and films are designed to work with a variety of solar technologies such as organic photovoltaics (OPV), CIGS, dye-sensitized solar cell (DSSC), and perovskites - making them an ideal choice for the flexible solar manufacturers of the future.

Designed for efficient roll-to-roll processing

Compatible with thin-film solar chemistries

Excellent weatherability helps ensure long-term module durability

Supports new applications in rooftop, transportation, personal electronics, & more

3M™ Ultra Barrier Solar Film

Typical Properties

Properties	Test Method	Typical Values*	Comment
Water Vapor Transmission Rate	Mocon, Aquatran	< 6×10^{-5} g/m²/day	@50°C 100% RH

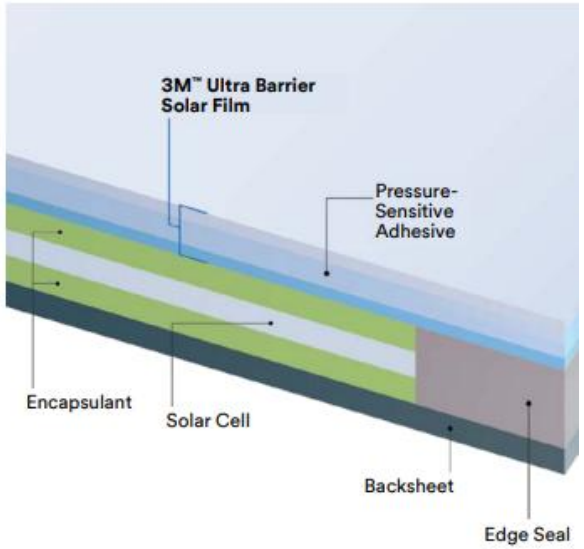
Features

- Good optical transmission from 400 – 1400 nm
- Very low moisture vapor transmission rate
- Excellent UV stability
- Flexible

Key Highlights

- UL Certified Component (E316895)
- WVTR: < 6×10^{-5} g/m²/day @ 50°C, 100% RH
- Transmission > 90% (Avg 400 nm – 1400 nm)
- Low Shrinkage: 0.15%
- Partial Discharge 1,000V
- Low CTE

Typical Flexible PV Module Construction



3M™ Charge-Collection Solar Tape 3011

Applications

3M Charge-Collection Solar Tape 3011 and 3011B are designed for use as a charge collector or bus within a thin-film solar module. 3M Charge-Collection Tape 3011B is designed for applications that require the bus on the front side of the module. The adhesive was formulated to undergo the vacuum lamination process typically used in the manufacture of solar modules.

3M™ Adhesive Transfer Tape 966

The 3M™ Adhesive Transfer Tapes with 3M™ High Temperature Acrylic Adhesive 100 are designed for temperature exposure to 450°F (232°C) for short periods of time and/or solvent resistance. They have exceptional shear values even at elevated temperatures. They also offer low “outgassing” properties, which is an important consideration for the aerospace, automotive and electronic industries.

HALE UAVs need enhanced light capture at low angles

Light capture by solar cells on HALE UAVs is reduced at low angles of incidence (dawn, dusk, high/low latitudes, winter)

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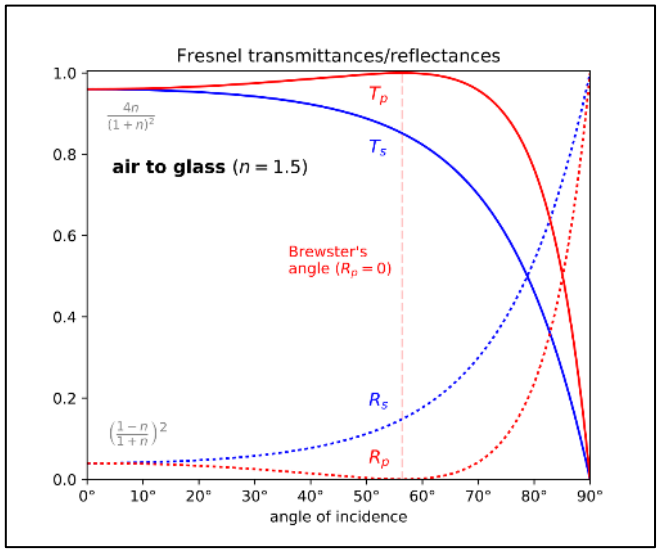
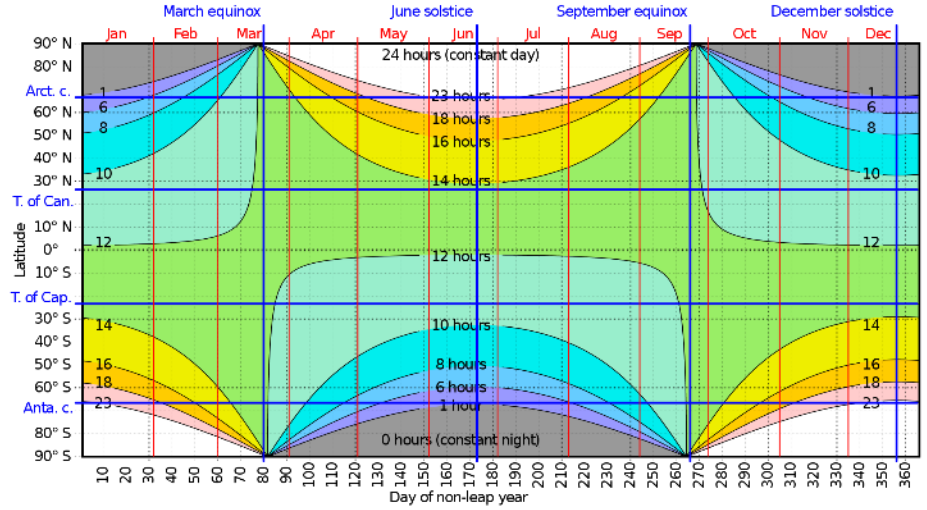
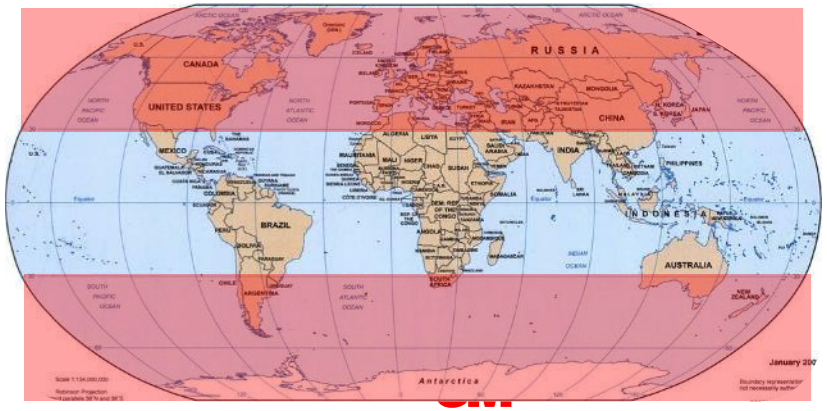


Sbergjohansen CC BY-SA 4.0



SebastianHelm - Modified File:Hours of daylight vs latitude vs day of year cmglee.svg by adding the tropical and polar circles instead of the 40° latitude highlighted. CC BY-SA 4.0

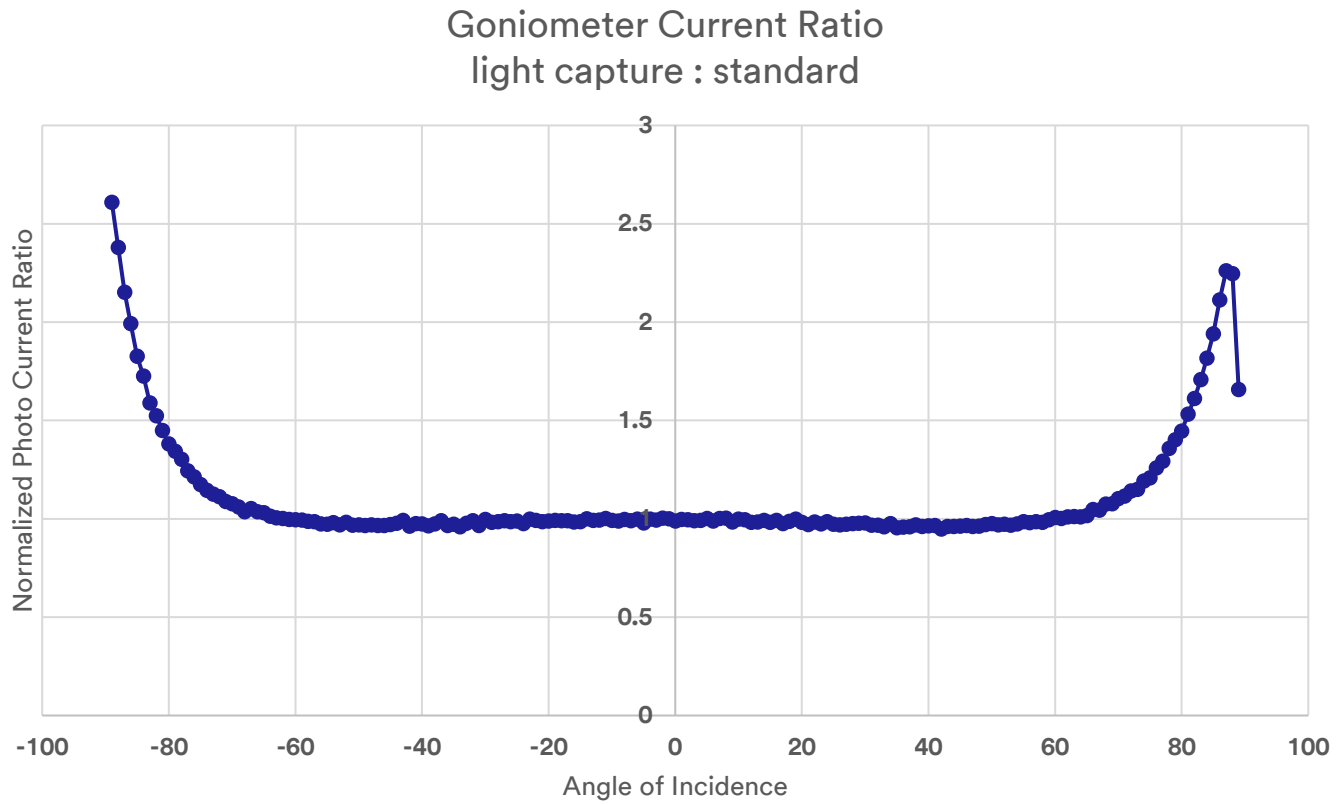
Limited to ~<30-35° latitude



Application need:

- Boost PV light capture
- Lightweight (<65 g/m2)
- Environmentally stable
  - 20-30km
  - -60C to +90C
  - Terrestrial solar spectrum with some UVC

Lightweight films to increase low angle light capture



- Film increases light capture above ~60°, up to 2.5x more than standard film
- Film is lightweight. ~15 g/m2 compared to 54 g/m2 for 1 mil FEP
- Film is durable. No decrease in transmission after >13k ESH terrestrial solar weathering

Encapsulant films for satellite solar cell arrays

Advantages

- Easy to use and scale (R2R processing)
- Domestic supply
- Additional functionality can be incorporated (moisture barrier, low angle light capture, adhesives)

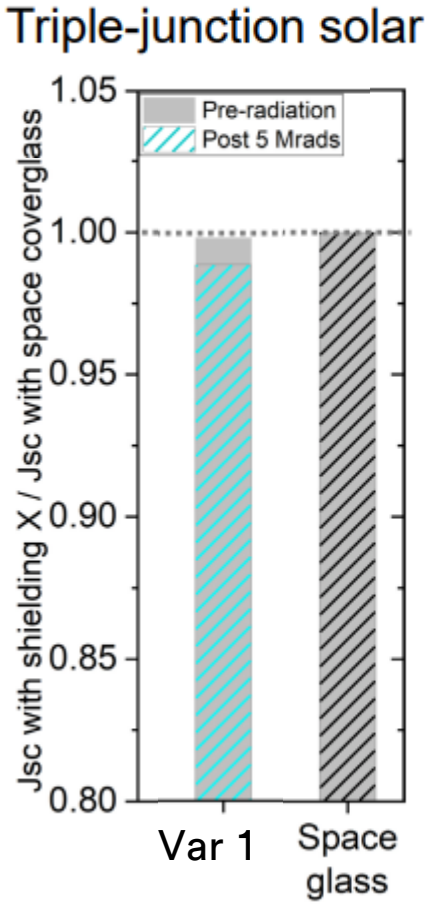
Performance requirements

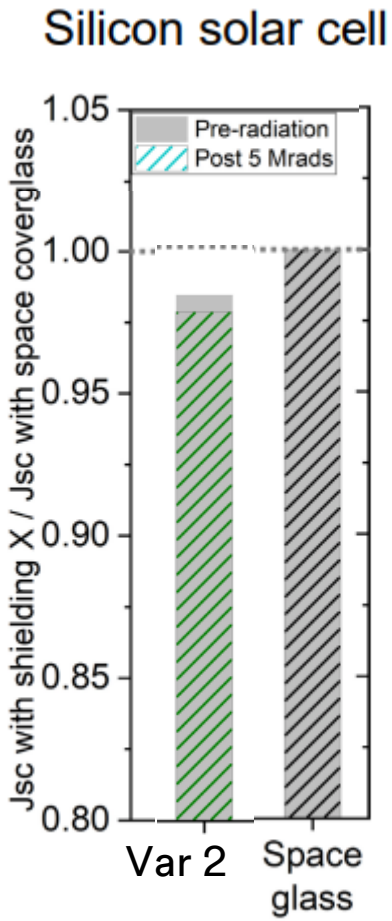
- Low earth orbit durable (AM0, AO, e-/p+ radiation)
- High visible transparency
- Stable ~-100C to +120C
- Low outgassing

3M encapsulant film summary

Comparable performance to space glass

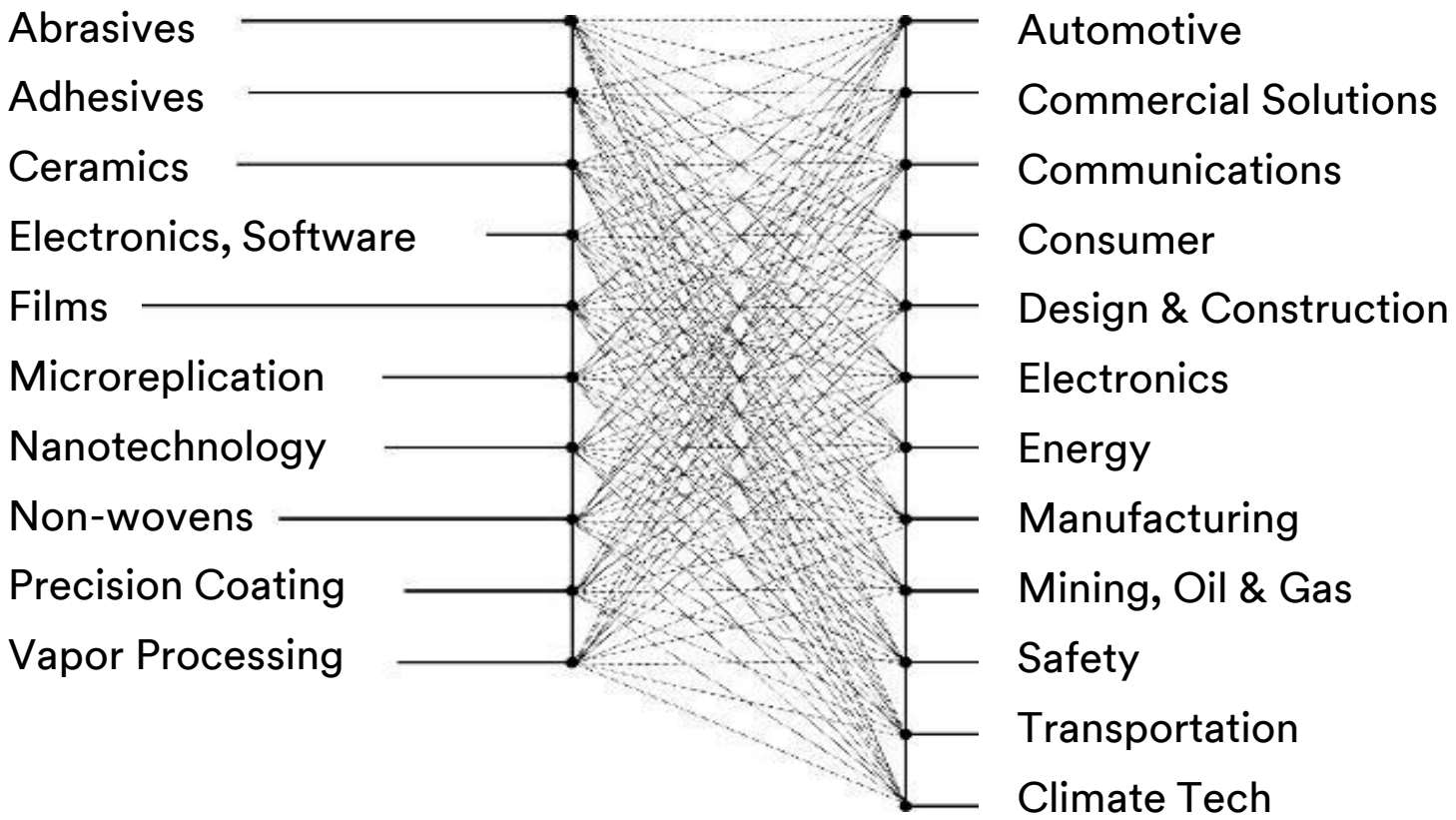
- AO, e-/p+ durable
- Low outgassing
- Retains 90% transmission at 25,000 ESH AM0
- Vacuum UV weathering underway
- Films can incorporate additional functionality/features





Technology Platforms

Markets



Making uncommon connections and innovating – that is what we do!



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Thank you!