

3M

Science.
Applied to Life.™

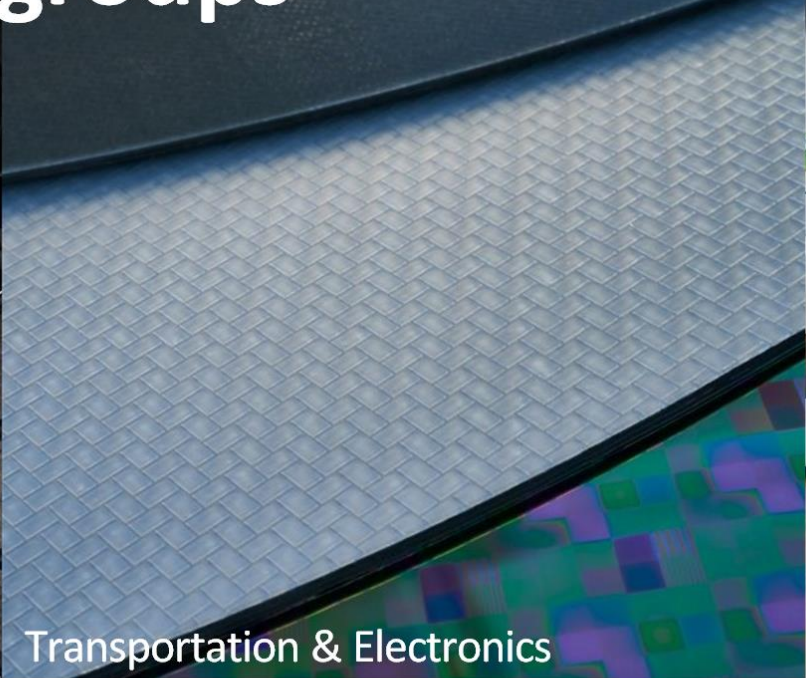
3M encapsulant films for satellite solar cell arrays

Serving our customers through three business groups



Safety & Industrial

Transforming how work gets done



Transportation & Electronics

Solving tough customer challenges to advance a connected world



Consumer

Bringing 3M to the hearts and minds of consumers

Ab

Abrasives

Ad

Adhesives

Ce

Ceramics

Cm

Circular Materials

Co

Advanced Composites

Em

Electronic Materials

Fi

Films

Mm

Metamaterials

Nt

Nano-technology

Nw

Nonwovens

Pm

Performance Materials

Ps

Polymer Science

Am

Additive Manufacturing

Mr

Micro-replication

Pp

Polymer Processing

Rm

Release Materials

Sm

Specialty Materials

Ch

Chemical Processing

Pc

Precision Coating & Web Processing

Rp

Radiation Processing

Mo

Molding

Pd

Particle & Dispersion Processing

Vp

Vapor Processing

Cv

Computer Vision

Ms

Modeling & Simulation

Ro

Advanced Robotics

Ds

Data Science & Analytics

Es

Electronic Systems

Ss

Software Solutions

An

Analytical Science

Is

Interface & Surface Science

As

Automation Solutions

Cp

Converting & Packaging

In

Inspection & Measurement

We

Accelerated Weathering

Ac

Acoustic Management

Ct

Climate Technology

Di

Display Components

Ec

Energy Components

Eg

Engineered Graphics

En

Energy Management

Fe

Flexible Electronics

Fs

Filtration & Separations

Lm

Light Management

Mf

Mechanical Fasteners

Tm

Thermal Management

Materials

Processes

Digital

Capabilities

Applications

Technology Platforms

Markets

Abrasives

Adhesives

Ceramics

Electronics, Software

Films

Microreplication

Nanotechnology

Non-wovens

Precision Coating

Vapor Processing

Automotive

Commercial Solutions

Communications

Consumer

Design & Construction

Electronics

Energy

Manufacturing

Mining, Oil & Gas

Safety

Transportation

Climate Tech

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

3M™ Ultra Barrier Solar Film





Typical Properties

Properties	Test Method	Typical Values*	Comment
Water Vapor Transmission Rate	Mocon, Aquatran	$< 6 \times 10^{-5}$ g/m ² /day	@50°C 100% RH

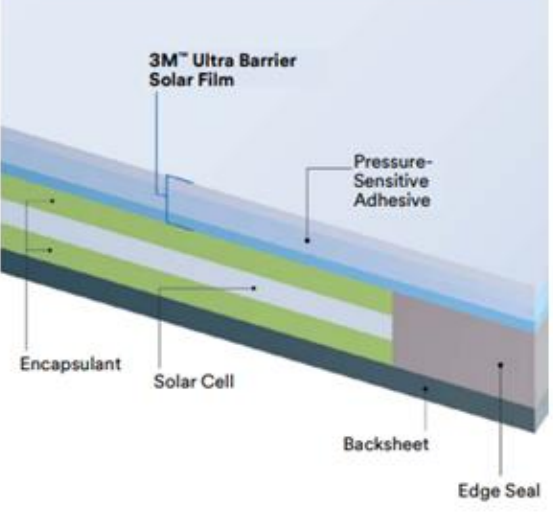
Features

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

Key Highlights

- UL Certified Component (E316895)
- WVTR: $< 6 \times 10^{-5}$ 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.

3M 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)



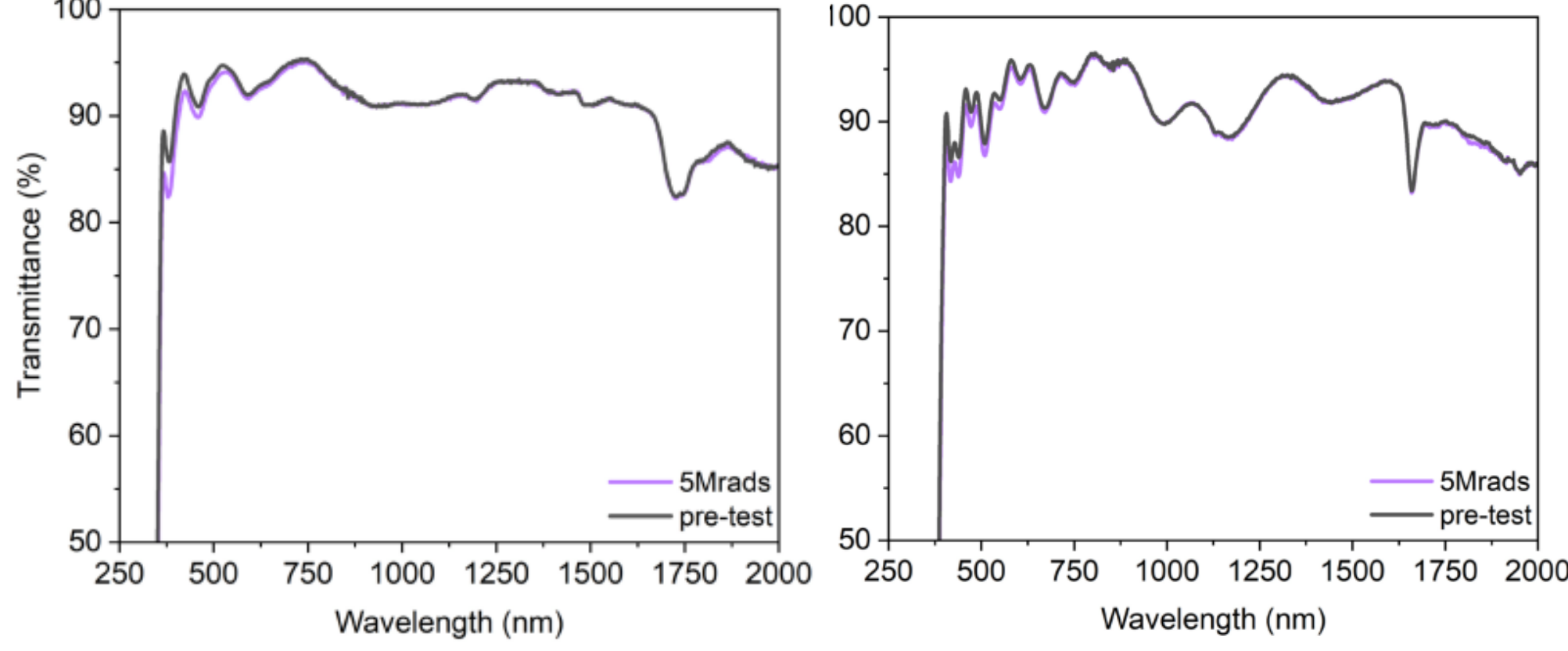
Performance requirements

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

Minor degradation after 5 Mrad gamma radiation

Variant 1

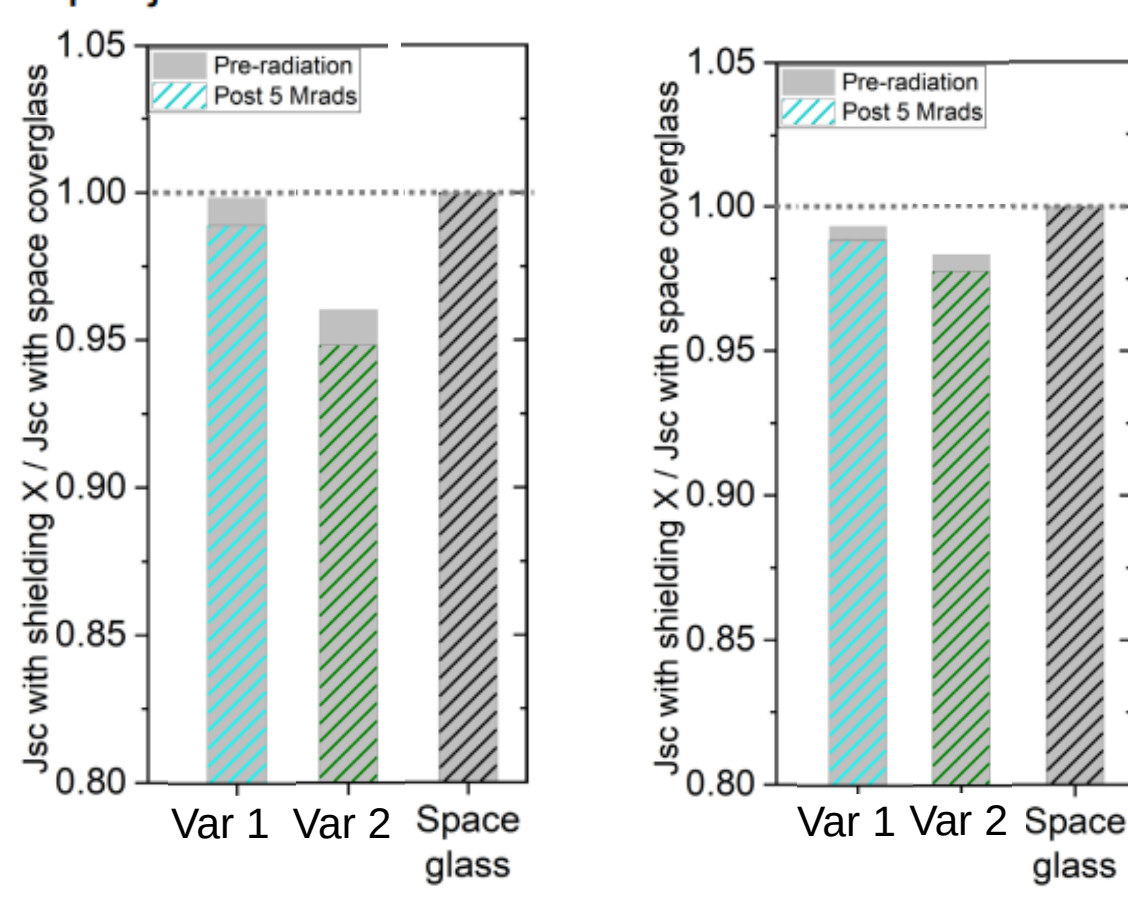
Variant 2



Comparable calculated Jsc to traditional space glass

Triple-junction solar cell

Silicon solar cell



Data in this box provided by Aerospace Corporation

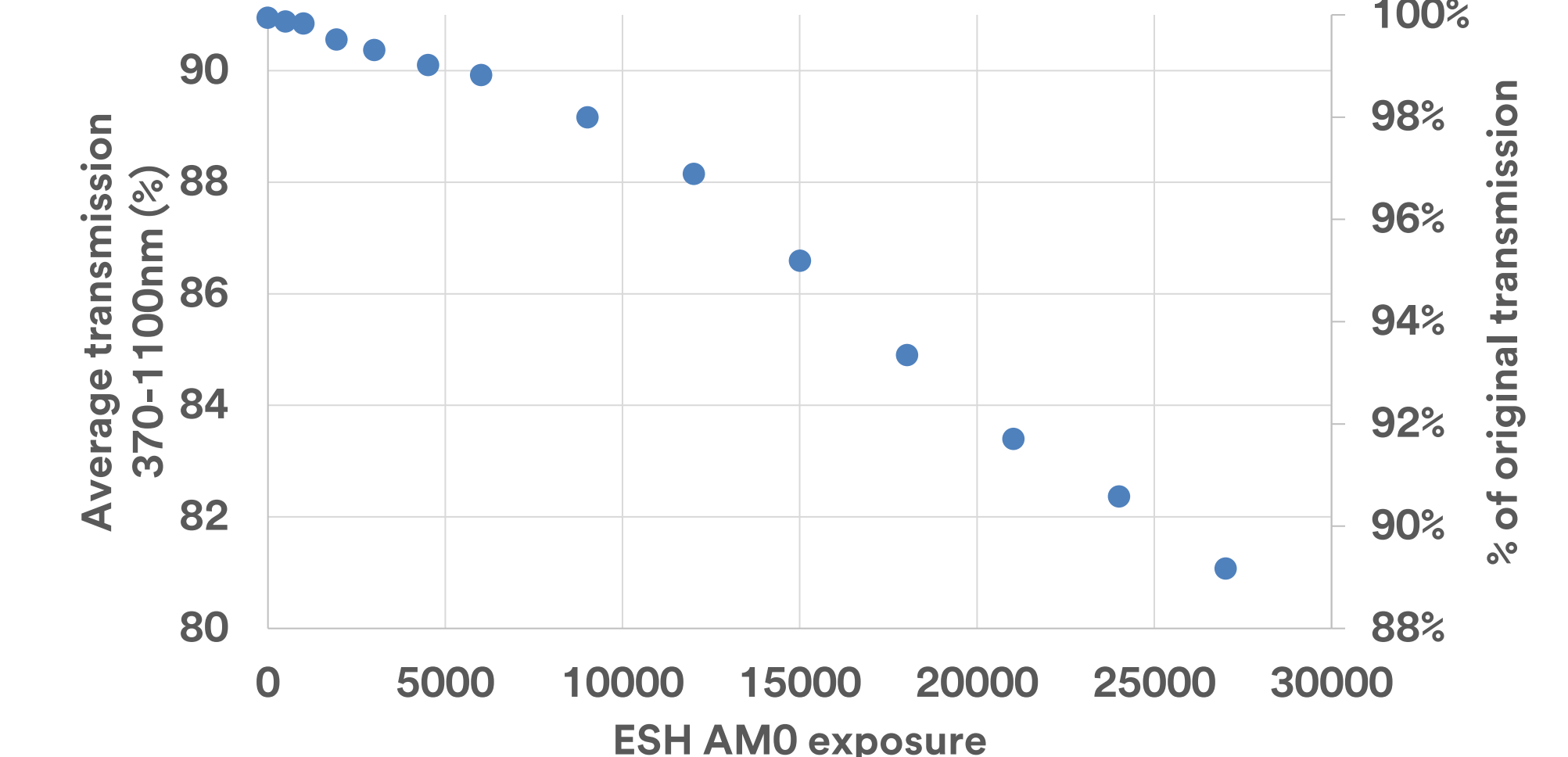
Gamma Radiation testing and Jsc Calculations: Pilar Espinet Gonzalez

E595 Outgas Testing: Abraham N. Buditama and Pilar Espinet Gonzalez

Passes E595 vacuum outgassing

Polymer Substrate Type	Total mass loss (%) (Target <1.0%)	Collected volatile condensable materials (%) (Target <0.1%)
Variant 1	0.998 +/- 0.284%	0.035 +/- 0.013%
Variant 2	0.275 +/- 0.004%	0.002 +/- 0.007%

Retains 95%/90% T0 transmission after 15,000/25,000 ESH AM0 (in atmosphere)



<0.1% mass loss after 1E21 atoms/cm2 atomic oxygen exposure

	1E21 atoms/cm2 exposure		
Material	Mass retention (%)	Mass loss per atom (mg/atom)	Erosion yield (cm3/atom)
3M Solar cell film	99.94%	1.9E-23	1.5E-26
Kapton for reference			2.8E-24
FEP for reference			2.0E-25

Future work

- Ground-based testing: vacuum AM0 testing (in progress), thermal cycling, combined effects
- Customer sampling and feedback
- On-orbit testing (MISSE, smallsats, customer satellites)