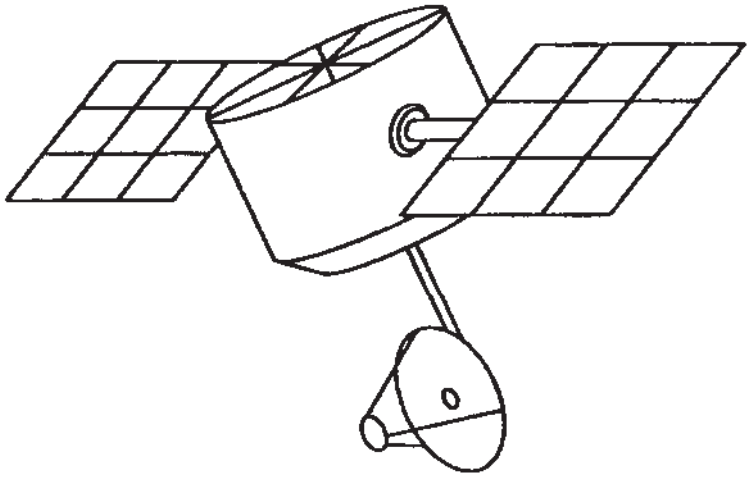


Materials for:

SPACECRAFT THERMAL CONTROL

Astral Technology Unlimited, Inc.

1611 Riverview Lane • Northfield, Minnesota 55057
Phone 507/645-0935 • Fax 507/663-8807
Toll Free 888/244-0664 • Email atu@clear.lakes.com
Website www.astraltechnology.com

Table of Contents

WHAT ARE SPACECRAFT THERMAL CONTROL MATERIALS

AND WHY ARE THEY USED?

All spacecraft are subject to wide temperature fluctuations. This temperature range can be as severe as -100°C to +150°C (-150°F to +300°F) depending on whether the spacecraft is in low earth orbit, geosynchronous orbit, synchronous orbit, or interplanetary orbit and whether the spacecraft is in a spin or stationary mode. The cold temperatures result from the spacecraft surfaces being in the earth's shadow or its own shadow. The high temperatures are caused by the sun shining on the spacecraft surface and from heat generated by electronic instrumentation on board. It is desirable to maintain the spacecraft between 20°C and 40°C (68°F and 105°F). This is accomplished by using both passive and active thermal control systems.

Active thermal control is usually battery powered electric heaters keeping spacecraft components warm during cold cycles.

Passive thermal control involves the materials this brochure describes. The materials are designed to have a specific "absorption" so that the amount of the sun's heat energy that is absorbed and the amount that is reflected is carefully controlled. Another property that all surfaces have is called "emittance" which is a measure of the ability of a surface to radiate or give off heat. This property is also carefully controlled. By controlling both the absorptance and emittance properties of a spacecraft surface, one can control the temperature of that surface.

To better understand what is meant by absorptance and emittance, consider the following illustrations. We all understand absorptance by the way we dress on a hot day while out in the sun. If one wears white, one feels cooler because much of the sun's heat energy is reflected and the absorption of heat is small. However, if one wears black, one feels very warm because there is very little reflection of the sun's heat energy and the absorption of heat is very high.

Emittance may be more difficult to relate to. One illustration might be a situation where the sun is shining on a concrete wall all afternoon. The sun goes down and the night air becomes cool. If you stand next to that wall but not touching it, you will feel warmth emitted or radiated from the wall.

Simply speaking, passive spacecraft thermal control can be achieved if one has just three materials. Those materials are white paint, black paint and aluminum foil.

If such simple materials can be used to achieve thermal control, why use exotic materials such as this brochure specifies? The reason is to achieve optimum thermal-optical properties along with lighter weight, longer lifetime, atomic oxygen resistance, and protection from UV, protons, electrons, soft x-rays and spacecraft charging. These materials are also easier to use, apply and if necessary, repair.

Astral Technology thermal control materials are used as covers for sunshades, radiators, antennas, structural members; spiral wrap for fuel lines and electric cable bundles as well as Multi-Layer-Insulation (MLI) blankets.

MATERIALS AND RELATED ABSORPTANCE/EMITTANCE PROPERTIES

ABSORPTANCE

A material that has low solar absorptance will have high reflectance and is silver or white in appearance. Silver metal has the lowest known solar absorptance of about 0.06. Other metals and paints are all higher. Some typical solar absorptance values are:

SILVER	0.06 - 0.09
ALUMINUM	0.10 - 0.14
COPPER/GOLD	0.20 - 0.30
WHITE PAINT	0.20 - 0.30
NIOBIUM	0.40 - 0.45
GERMANIUM	0.45 - 0.55
INCONEL	0.60 - 0.70
CHROMIUM	0.70 - 0.80
BLACK PAINT	0.80 - 0.95

INFRARED EMITTANCE

Low emittance values can generally be equated to materials that are good electrical conductors and high emittance to materials that are good dielectrics or electrical insulators. Gold and silver have very low emittance values while plastic films have high emittance values. Some typical infrared emittance values are:

GOLD	0.02 - 0.03
ALUMINUM	0.03 - 0.05
CHROMIUM	0.10 - 0.20
GERMANIUM	0.50 - 0.80
PLASTIC FILMS	0.30 - 0.90
WHITE PAINT	0.85 - 0.95
BLACK PAINT	0.85 - 0.95

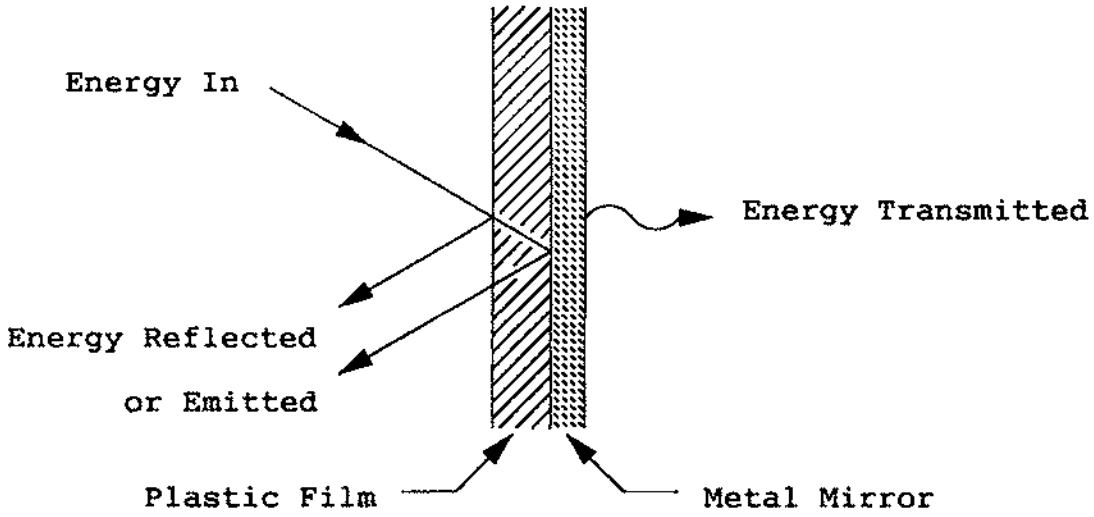
The above coatings are often used in thermal control materials.

The materials in this brochure use high performance plastic films as a substrate for application of the thermal control coatings. In many cases the plastic film functions along with the coatings to produce high emittance. These are called second surface mirrors where the optical properties are obtained by "looking through" the plastic film at the metal mirror behind. When plastic films are used this way, the thickness of the film determines what the emittance will be. To illustrate:

TYPICAL INFRARED EMITTANCE OF PLASTIC FILMS

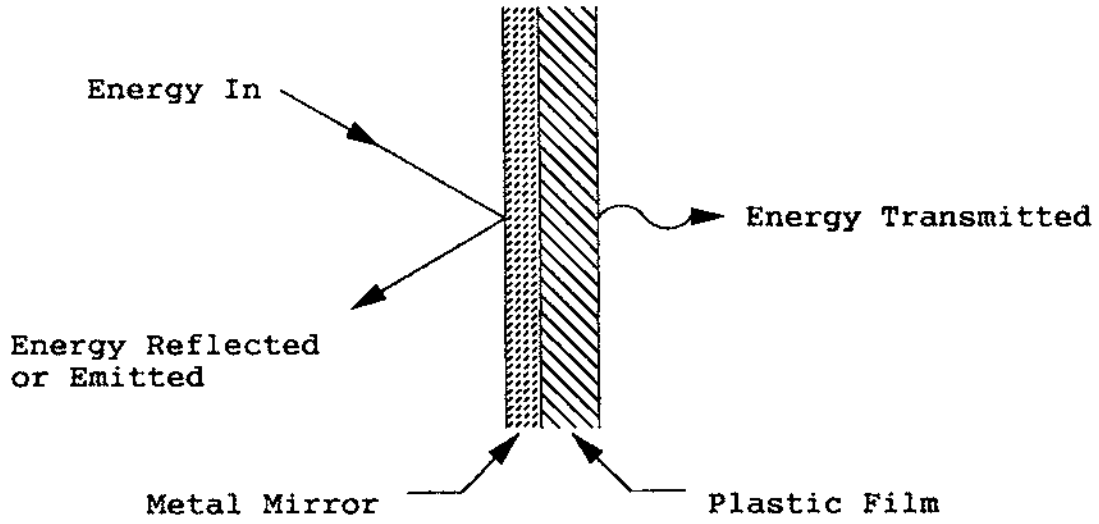
Film Thickness	FEP Teflon	Kapton	Mylar
7 micron (0.3 mil)	----	0.50	0.33
13 micron (0.5 mil)	0.40	0.56	0.46
25 micron (1 mil)	0.50	0.70	0.57
50 micron (2 mil)	0.60	0.79	0.72
75 micron (3 mil)	----	0.85	0.77
125 micron (5 mil)	0.77	0.93	0.81

ILLUSTRATION OF A SECOND SURFACE MIRROR



In other situations the plastic films are used as a substrate carrier only for the thermal control coatings. These are called First Surface Mirrors.

ILLUSTRATION OF A FIRST SURFACE MIRROR



In some cases materials with a certain set of optical properties will be applied to one side of the film and materials with a different set to the other side. Pressure sensitive adhesives can be applied to one side of the film to provide for easy attachment to other surfaces or a cloth reinforcement can be laminated to one side to add strength and tear resistance. The films can be perforated to allow for venting or outgassing.

SURFACE COATINGS, SHIELDS AND MULTILAYER INSULATION BLANKETS

SURFACE COATINGS

Thermal control tapes (i.e. those narrow films having a thermal control coating on one side and a pressure sensitive adhesive) are often applied to outer or exposed surfaces of a spacecraft. This includes items like spiral wrapping fuel lines, electric cable bundles, structural members, etc., and also includes covering larger areas such as radiator surfaces.

SHIELDS

At times there are substantial open areas on the surface of a spacecraft. These can be closed out by fabricating a lightweight frame that attaches to the perimeter of the open area and applying a shield or sunshade of thermal control material to the frame. This prevents sunlight from getting inside the spacecraft and causing undesired thermal excursions.

MULTILAYER INSULATION BLANKETS

In general, Multi-Layer Insulation (MLI) is a type of high performance insulator which uses multiple radiation heat transfer barriers to retard the flow of thermal energy. The design of a MLI blanket requires consideration of many other parameters in addition to thermal performance. Some of these parameters are 1) Environmental considerations such as UV, electrons, protons, soft x-rays, atomic oxygen, static charge build up and exposure temperatures. 2) Physical considerations such as durability, flexibility, weight, ease of attachment to and removal from a spacecraft, strength retention after various stages of handling and fabrication, electrical grounding and ability to withstand launch loads and vibration. 3) Fabrication methods such as sewing, heat sealing, stapling or adhesive bonding.

All of these parameters when considered collectively will determine the materials of construction such as the outer blanket covers, infrared shields, spacers, insulating felts, sewing threads, adhesives, Velcro, lacing, metal fasteners, etc.

It is easy to see that given all the choices of fabrication methods, materials and environmental considerations, one can come up with a multitude of various constructions. The following pages provide information on our product specifications and examples of some common thermal control materials. Astral Technology can assist in choosing the right material for the application and then use its capabilities to provide materials of the highest quality.

Examples of Thermal Control Materials

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m^2
ATU9128	STAMET/25 micron (1 mil) conductive black polyimide/4 x 4 NOMEX	≤0.50	≥0.80	≈0.57	≤ 60
ATU2110	Aluminum/25 micron (1 mil) polyimide/ 3M 966 acrylic adhesive	≤0.14	≤0.05	≈4.0	≤121
ATU2220	50 micron (2 mil) polyimide/aluminum/ 3M 966 acrylic adhesive	≤0.44	≥0.71	≈0.50	≤160
ATU9027	ITO/125 micron (5 mil) FEP/silver/ Inconel/3M 966 acrylic adhesive	≤0.10	≥0.75	≈0.09	≤385
ATU2510	Gold/25 micron (1 mil) polyimide/ 3M 966 acrylic adhesive	-	≤0.03	-	≤121

POLYIMIDE/ALUMINUM ROLL GOODS

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -250°C. to +150°C.

Continuous temperature range: -250°C. to +150°C.

Resistivity of ITO: ≤ 1,000 ohms/square

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m^2
ATU1110	25 micron (1 mil) polyimide/aluminum	≤0.39	≥0.62	≈0.50	≤ 40
ATU1120	50 micron (2 mil) polyimide/aluminum	≤0.44	≥0.71	≈0.50	≤ 78
ATU1130	75 micron (3 mil) polyimide/aluminum	≤0.46	≥0.77	≈0.50	≤116
ATU1510	ITO/25 micr (1 mil) polyimide/aluminum	≤0.39	≥0.62	≈0.50	≤ 40
ATU1520	ITO/50 micr (2 mil) polyimide/aluminum	≤0.44	≥0.71	≈0.50	≤ 78
ATU1530	ITO/75 micr (3 mil) polyimide/aluminum	≤0.46	≥0.77	≈0.50	≤116

NOTE: A layer of silicon dioxide (SiO2) can be deposited on the surface of polyimide film to provide protection from atomic oxygen erosion. If desired, ITO can be deposited on the top of SiO2 to provide electrical conductivity for draining static charges.

These products are available 46 to 48 inches wide in continuous rolls and may be perforated to provide MLI blanket venting or for plated through interconnects which connect the ITO side to the metal side electrically. See page 20 for available perforating patterns.

FEP/ALUMINUM ROLL GOODS

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -185°C. to +125°C.

Continuous temperature range: -185°C. to +125°C.

Resistivity of ITO: ≤ 1,000 ohms/square

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m^2
ATU3110	25 micron (1 mil) FEP/aluminum	≤0.14	≥0.48	≈0.24	≤ 60
ATU3120	50 micron (2 mil) FEP/aluminum	≤0.14	≥0.60	≈0.19	≤120
ATU3150	125 micron (5 mil) FEP/aluminum	≤0.14	≥0.75	≈0.15	≤300
ATU3180	250 micron (10 mil) FEP/aluminum	≤0.15	≥0.85	≈0.14	≤600
ATU3310	ITO/25 micron (1 mil) FEP/aluminum	≤0.14	≥0.48	≈0.24	≤ 60
ATU3320	ITO/50 micron (2 mil) FEP/aluminum	≤0.14	≥0.60	≈0.19	≤120
ATU3350	ITO/125 micron (5 mil) FEP/aluminum	≤0.14	≥0.75	≈0.15	≤300
ATU3380	ITO/250 micron (10 mil) FEP/aluminum	≤0.15	≥0.85	≈0.15	≤600

These products are available 46 to 48 inches wide in continuous rolls and may be perforated to provide MLI blanket venting or for plated through interconnects which connect the ITO side to the metal side electrically. See page 20 for available perforating patterns.

FEP/SILVER/INCONEL ROLL GOODS

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -185°C. to +125°C.

Continuous temperature range: -185°C. to +125°C.

Resistivity of ITO: ≤ 1,000 ohms/square

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m²
ATU9157	25 micron (1 mil) FEP/silver/Inconel	≤0.09	≥0.48	≈0.14	≤ 60
ATU9036	50 micron (2 mil) FEP/silver/Inconel	≤0.09	≥0.60	≈0.11	≤120
ATU9015	125 micron (5 mil) FEP/silver/Inconel	≤0.09	≥0.75	≈0.09	≤300
ATU9022	250 micron (10 mil) FEP/silver/Inconel	≤0.10	≥0.85	≈0.11	≤600
ATU9156	ITO/25 micron (1 mil) FEP/silver/Inc	≤0.10	≥0.48	≈0.17	≤ 60
ATU9035	ITO/50 micron (2 mil) FEP/silver/Inc	≤0.10	≥0.60	≈0.15	≤120
ATU9030	ITO/125 micron (5 mil) FEP/silver/Inc	≤0.10	≥0.75	≈0.12	≤300
ATU9037	ITO/250 micron (10 mil) FEP/silver/Inc	≤0.11	≥0.85	≈0.13	≤600

These products are available 46 to 48 inches wide in continuous rolls and may be perforated to provide MLI blanket venting or for plated through interconnects which connect the ITO side to the metal side electrically. See page 20 for available perforating patterns.

FEP/SILVER/NIOBIUM ROLL GOODS

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -185°C. to +125°C.

Continuous temperature range: -185°C. to +125°C.

Resistivity of ITO: ≤ 1,000 ohms/square

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m²
ATU3210	25 micron (1 mil) FEP/silver/Niobium	≤0.09	≥0.48	≈0.14	≤ 60
ATU3220	50 micron (2 mil) FEP/silver/Niobium	≤0.09	≥0.60	≈0.11	≤120
ATU3250	125 micron (5 mil) FEP/silver/Niobium	≤0.09	≥0.75	≈0.09	≤300
ATU3280	250 micron (10 mil) FEP/silver/Niobium	≤0.10	≥0.85	≈0.11	≤600
ATU3410	ITO/25 micron (1 mil) FEP/silver/Nb	≤0.10	≥0.48	≈0.17	≤ 60
ATU3420	ITO/50 micron (2 mil) FEP/silver/Nb	≤0.10	≥0.60	≈0.15	≤120
ATU3450	ITO/125 micron (5 mil) FEP/silver/Nb	≤0.10	≥0.75	≈0.12	≤300
ATU3480	ITO/250 micron (10 mil) FEP/silver/Nb	≤0.11	≥0.85	≈0.13	≤600

These products are available 46 to 48 inches wide in continuous rolls and may be perforated to provide MLI blanket venting or for plated through interconnects which connect the ITO side to the metal side electrically. See page 20 for available perforating patterns.

GERMANIUM/BLACK KAPTON ROLL GOODS

Germanium is a coating that is often used as an antenna cover because it transmits RF energy with little loss, but still bleeds static charge and keeps the antenna cool.

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -250°C. to +150°C.

Continuous temperature range: -250°C. to +150°C.

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m^2
ATU9017	Germanium/25 micron (1 mil) non-conductive black polyimide	≤0.50	≥0.80	≈0.57	≤ 40
ATU9040	Germanium/25 micron (1 mil) non-conductive black polyimide/4 x 4 NOMEX	≤0.50	≥0.80	≈0.57	≤ 60
ATU9019	Germanium/25 micron (1 mil) conductive black polyimide	≤0.54	≥0.80	≈0.57	≤ 40
ATU9111	Germanium/25 micron (1 mil) conductive black polyimide/4 x 4 NOMEX	≤0.54	≥0.80	≈0.57	≤ 60
ATU9013	Germanium/25 micron (1 mil) conductive black polyimide/aluminum	≤0.54	≥0.80	≈0.57	≤ 40
ATU9124	Germanium/25 micron (1 mil) conductive black polyimide/aluminum/4 x 4 NOMEX	≤0.54	≥0.80	≈0.57	≤ 60

These products are available 46 to 48 inches wide in continuous rolls and may be perforated to provide MLI blanket venting. See page 20 for available perforating patterns.

STAMET/BLACK KAPTON ROLL GOODS

STAMET is an alloy developed as a substitute for germanium metal. All optical and electrical properties are similar to germanium with the added advantage of significantly improved corrosion resistance. Germanium has a history of corroding in high humidity environments. The corrosion that happens converts the germanium to germanium oxide which is transparent and gives the appearance that the germanium has disappeared. STAMET can be exposed to high humidity or even soaked in water with no affect on its optical or electrical properties.

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -250°C. to +150°C.

Continuous temperature range: -250°C. to +150°C.

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m²
ATU9140	STAMET/25 micron (1 mil) non-conductive black polyimide	≤0.50	≥0.80	≈0.57	≤ 40
ATU9139	STAMET/25 micron (1 mil) non-conductive black polyimide/4 x 4 NOMEX	≤0.50	≥0.80	≈0.57	≤ 60
ATU9148	STAMET/25 micron (1 mil) conductive black polyimide	≤0.50	≥0.80	≈0.57	≤ 40
ATU9128	STAMET/25 micron (1 mil) conductive black polyimide/4 x 4 NOMEX	≤0.50	≥0.80	≈0.57	≤ 60
ATU9138	STAMET/25 micron (1 mil) conductive black polyimide/aluminum	≤0.50	≥0.80	≈0.57	≤ 40
ATU9144	STAMET/25 micron (1 mil) conductive black polyimide/aluminum/4 x 4 NOMEX	≤0.50	≥0.80	≈0.57	≤ 60

These products are available 46 to 48 inches wide in continuous rolls and may be perforated to provide MLI blanket venting. See page 20 for available perforating patterns.

MISCELLANEOUS ROLL GOODS

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -250°C. to +150°C.

Continuous temperature range: -250°C. to +150°C.

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m²
ATU9098	25 micron (1 mil) conductive black polyimide/aluminum	≥0.93	≥0.84	≈1.0	≤ 40
ATU9127	25 micron (1 mil) conductive black polyimide/aluminum/4 x 4 NOMEX	≥0.93	≥0.84	≈1.0	≤ 60
ATU9048	25 micron (1 mil) conductive black polyimide/4 x 4 NOMEX	≥0.93	≥0.84	≈1.0	≤ 60
ATU9149	4 x 4 NOMEX netting	-	-	-	≤ 20
	Astral Technology offers a NOMEX netting for spacer material between heat shields in MLI blankets. It is woven in a 4 x 4 threads per inch pattern. It is easy to handle and typical weight is 16 grams per square meter.				
ATU9145-100CB = DuPont 100CB black Kapton		-	-	-	≤ 40
ATU9145-100XC = DuPont 100XC black Kapton		-	-	-	≤ 40
ATU9145-160XC = DuPont 160XC black Kapton		-	-	-	≤ 64
ATU9145-275XC = DuPont 275XC black Kapton		-	-	-	≤110

These products are available 46 to 48 inches wide in continuous rolls and may be perforated to provide MLI blanket venting. See page 20 for available perforating patterns.

SECOND SURFACE MIRROR ALUMINUM/POLYIMIDE TAPES

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -60°C. to +230°C.

Continuous temperature range: -60°C. to +120°C.

Adhesion: 20 oz/inch width per ASTM 1000[A]

A = At -45°C. this acrylic has a minima in its adhesion curve.

Resistivity of ITO: ≤ 1,000 ohms/square

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m^2
ATU2210	25 micron (1 mil) polyimide/aluminum/ 3M 966 acrylic adhesive	≤0.39	≥0.62	≈0.5	≤121
ATU2220	50 micron (2 mil) polyimide/aluminum/ 3M 966 acrylic adhesive	≤0.44	≥0.71	≈0.5	≤160
ATU2230	75 micron (3 mil) polyimide/aluminum/ 3M 966 acrylic adhesive	≤0.46	≥0.77	≈0.5	≤197
ATU2310	ITO/25 micron (1 mil) polyimide/ aluminum/3M 966 acrylic adhesive	≤0.39	≥0.62	≈0.5	≤121
ATU2320	ITO/50 micron (2 mil) polyimide/ aluminum/3M 966 acrylic adhesive	≤0.44	≥0.71	≈0.5	≤160
ATU2330	ITO/75 micron (3 mil) polyimide/ aluminum/3M 966 acrylic adhesive	≤0.46	≥0.77	≈0.5	≤197

FEP/SILVER/INCONEL TAPES

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -60°C. to +125°C.

Continuous temperature range: -60°C. to +125°C.

Adhesion: 20 oz/inch width per ASTM 1000[A]

A = At -45°C. this acrylic has a minima in its adhesion curve.

Resistivity of ITO: ≤ 1,000 ohms/square

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m²
ATU9155	25 micron (1 mil) FEP/Ag/Inconel/3M 966	≤0.09	≥0.48	≈0.14	≤146
ATU9059	50 micron (2 mil) FEP/Ag/Inconel/3M 966	≤0.09	≥0.60	≈0.11	≤206
ATU9018	125 micron (5 mil) FEP/Ag/Inconel/966	≤0.09	≥0.75	≈0.09	≤378
ATU9074	250 micron (10 mil) FEP/Ag/Inconel/966	≤0.10	≥0.85	≈0.11	≤670
ATU9101	ITO/25 micron (1 mil) FEP/Ag/Inc/966	≤0.10	≥0.48	≈0.17	≤146
ATU9158	ITO/50 micron (2 mil) FEP/Ag/Inc/966	≤0.10	≥0.60	≈0.15	≤206
ATU9027	ITO/125 micron (5 mil) FEP/Ag/Inc/966	≤0.10	≥0.75	≈0.12	≤378
ATU9159	ITO/250 micron (10 mil) FEP/Ag/Inc/966	≤0.11	≥0.85	≈0.13	≤670

FEP/SILVER/NIOBIUM TAPES

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -60°C. to +125°C.

Continuous temperature range: -60°C. to +125°C.

Adhesion: 20 oz/inch width per ASTM 1000^A

A = At -45°C. this acrylic has a minima in its adhesion curve.

Resistivity of ITO: ≤ 1,000 ohms/square

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m²
ATU4210	25 micron (1 mil) FEP/Ag/Niobium/3M 966	≤0.09	≥0.48	≈0.14	≤146
ATU4220	50 micron (2 mil) FEP/Ag/Niobium/3M 966	≤0.09	≥0.60	≈0.11	≤206
ATU4250	125 micron (5 mil) FEP/Ag/Niob/3M 966	≤0.09	≥0.75	≈0.09	≤378
ATU4280	250 micron (10 mil) FEP/Ag/Niob/3M 966	≤0.10	≥0.85	≈0.11	≤670
ATU4410	ITO/25 micron (1 mil) FEP/Ag/Niob/966	≤0.10	≥0.48	≈0.17	≤146
ATU4420	ITO/50 micron (2 mil) FEP/Ag/Niob/966	≤0.10	≥0.60	≈0.15	≤206
ATU4450	ITO/125 micron (5 mil) FEP/Ag/Niob/966	≤0.10	≥0.75	≈0.12	≤378
ATU4480	ITO/250 micron (10 mil) FEP/Ag/Niob/966	≤0.11	≥0.85	≈0.13	≤670

FEP/ALUMINUM TAPES

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -60°C. to +125°C.

Continuous temperature range: -60°C. to +125°C.

Adhesion: 20 oz/inch width per ASTM 1000[A]

A = At -45°C. this acrylic has a minima in its adhesion curve.

Resistivity of ITO: ≤ 1,000 ohms/square

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m^2
ATU4110	25 micron (1 mil) FEP/aluminum/3M 966	≤0.14	≥0.48	≈0.24	≤146
ATU4120	50 micron (2 mil) FEP/aluminum/3M 966	≤0.14	≥0.60	≈0.19	≤206
ATU4150	125 micron (5 mil) FEP/aluminum/966	≤0.14	≥0.75	≈0.15	≤378
ATU4180	250 micron (10 mil) FEP/aluminum/966	≤0.15	≥0.85	≈0.14	≤670
ATU4310	ITO/25 micr (1 mil) FEP/aluminum/966	≤0.14	≥0.48	≈0.24	≤146
ATU4320	ITO/50 micr (2 mil) FEP/aluminum/966	≤0.14	≥0.60	≈0.19	≤206
ATU4350	ITO/125 micr (5 mil) FEP/aluminum/966	≤0.14	≥0.75	≈0.15	≤378
ATU4380	ITO/250 micr (10 mil) FEP/aluminum/966	≤0.15	≥0.85	≈0.14	≤670

SPECIALTY TAPES

The materials listed on this page meet or exceed the following properties:

Outgassing: TML ≤ 1.0%, VCM ≤ 0.1% per ASTM E 595

Intermittent temperature range: -60°C. to +230°C.

Continuous temperature range: -60°C. to +120°C.

Adhesion: 20 oz/inch width per ASTM 1000[A]

A = At -45°C. this acrylic has a minima in its adhesion curve.

PART NUMBER	DESCRIPTION	α	ε	α/ε	WEIGHT gm/m^2
ATU2510	Gold/25 micron (1 mil) polyimide/3M 966 acrylic pressure sensitive adhesive	-	≤0.03	-	≤121
ATU2110	Aluminum/25 micron (1 mil) polyimide/ 3M 966 acrylic adhesive	≤0.14	≤0.05	4.0	≤121
ATU9075	25 micron (1 mil) non-conductive black polyimide/3M 966 acrylic adhesive	≥0.93	≥0.84	≈1.0	≤121
ATU9043	25 micron (1 mil) conductive black polyimide/3M 966 acrylic adhesive	≥0.93	≥0.84	≈1.0	≤121
ATU9109	Germanium/25 micron (1 mil) conductive black polyimide/3M 966 acrylic adhesive	≤0.54	≥0.80	≈0.57	≤121

Miscellaneous

Films

The polyimide film we use is DuPont Kapton (registered trademark).
The FEP film we use is DuPont Teflon (registered trademark).

Tapes

Tape widths are incremental from 0.5 inch to 24 inches.

Standard tape length is 108 feet.

The following optional adhesives are available for tape:
- 3M 9460: thickness = 50 microns (2.0 mils)
- 3M 9461: thickness = 25 microns (1.0 mil)
- 3M 9703: thickness = 50 microns (2.0 mils)
  This adhesive is electrically conductive.

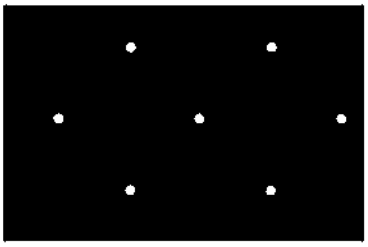
All adhesives meet NASA outgassing requirements of ≤1.0% TML and ≤0.1% VCM per ASTM E 595.

All tapes are available with optional protective overlay.

All tapes are available with optional perforations.

Perforations

The following are ATU standard perforation patterns.



059/0750/DIA (Pattern 102)
0.97% open

059/0936/STR
0.31% open

Documentation

All thermal control materials include at no extra charge:
- o Complete traceability on all raw materials
- o Certification of Compliance
- o Test data on optical properties

Niobium

We believe there are two reasons why the Niobium protected silver FEP products maintain their optical properties better than Inconel coated silver FEP products.

First: Both FEP and silver are soft and flexible. The Inconel is quite brittle. When the FEP is flexed and/or stretched from handling or temperature expansion/contraction, the Inconel breaks up into fairly large "islands." The area between the islands is no longer protected and the silver darkens and degrades from contamination and UV exposure. Niobium is much more flexible and moves with the FEP and silver - maintaining coating integrity and resulting in better protection.

Second: Inconel contains approximately 6 to 14 percent iron. We believe the iron reacts with the silver over time when there is enough energy present, mainly from UV exposure.

All of our testing and all space qualification testing by a major aerospace company show that the End of Life (EOF) absorptance values are nearly identical to Beginning of Life (BOL) absorptance values for the Niobium product versus a rise of 300 to 600 percent for standard Inconel products.

Surface Modification

An optional roll-to-roll process called grit blasting is used to surface texture or roughen a film's surface which reduces specular reflectance below 0.01 after metalizing. Sunlight concentration on certain areas can be reduced or eliminated by using surface textured films. Films up to 50 inches wide and 1 mil thick or thicker can be processed.

Working with Thermal Control Materials

PACKAGING
Thermal control materials are packaged in sealed polyethylene bags with desiccant, wrapped with bubble poly and placed in a cardboard box using core pads.

Germanium coated films are packaged differently using a two bag system made from MIL-PRF-22191, type 1 packaging material. The film is placed in the first bag, purged with dry nitrogen and sealed. This package is placed in a second bag with desiccant, sealed, wrapped with bubble poly and placed in a cardboard box. These bags must not be opened until ready to use the germanium coated film.

FABRICATION
Fabrication of thermal control materials should take place in an enclosed clean room area with controlled temperature and reduced humidity (less than 70% R.H.). Floors should be nondusting and the walls and ceilings free of flaking, chipping, or other particle producing features. Table tops should be covered with Tedlar or Mylar and kept free of dirt, grit and other contaminates. The area should be cleaned daily when fabricating operations produce visible contamination.

Cutting of T/C materials using a template and razor or other blades that require a cutting surface for the blade to cut into should be done using a polyurethane cutting board or thin sheet of polycarbonate or acrylic. Obviously, cutting boards should be replaced on a regular basis. Thermal control materials should be covered when not in use to prevent the accumulation of dust or dirt on the film surface.

HANDLING
Use care in removing thermal control materials from the packaging and during handling. One must avoid three-cornered folds and sliding of the material on table surfaces or the sliding of films on other films. Excessive handling and folding or slight surface scratches can severely degrade the electrical continuity of the thin and fragile metal and ITO coatings.

Thermal control tapes should be applied using a hard rubber roller or by rubbing with a thumb or finger. In the latter case especially, we recommend using a protective overlay on the tape to prevent damage to the thermal control surface.

PERSONNEL
Smocks and clean room head covering should be worn. Personnel must wear clean room gloves (PVC or latex). We also recommend wearing a mask over the mouth since speaking can cause small droplets of saliva to fall on the material and quickly cause corrosion in small dots. Food or drink can not be allowed in the controlled area.

CLEANING
If germanium films become contaminated, clean using a soft camel's hair brush and if necessary, isopropanol on a clean room rag may be used with care to remove contamination. Do not use excessive amounts of isopropanol.

SPUTTERED MATERIALS

Astral Technology has targets and processes to produce the following sputtered materials.

- Aluminum
- Aluminum Nitride
- Aluminum Oxide
- Chromium
- Chromium Oxide
- Chromium Nitride
- Constantan
- Copper
- Germanium
- Germanium Oxide
- Gold
- Inconel 600
- Indium-Tin-Oxide
- Lead Oxide
- Molybdenum
- Nichrome
- Nichrome Oxide
- Nichrome Nitride
- Nickel
- Niobium
- Niobium Oxide
- Silicon
- Silicon/Aluminum alloys
- Silicon Dioxide
- Silicon Nitride
- Silver
- Tantalum Niobium
- Tin
- Tin Oxide
- Titanium
- Titanium Oxide
- Titanium Nitride
- Specialty alloys

GENERAL CAPABILITIES

Astral Technology Unlimited, Inc. was founded to provide research, development and short run production of vacuum metalized films and thin film coatings to the scientific and technical community. Some of this work has resulted in our offering products in very specialized areas.

PRODUCTS

Spacecraft Thermal Control Materials are tapes and films that have controlled absorptance/emittance properties to passively control the temperature of a spacecraft.

Low Observable Materials have controlled electrical resistance properties or controlled infrared reflectance/absorptance properties and sometimes have specific patterns laser etched into the coatings. Applications are mainly "stealth" craft.

Electrical/Electronic Materials include a variety of materials ranging from ultra thin films used in transducers, microphones and headphones to more standard films used in circuits, flexswitches, displays, heaters and antennas. These films are coated on one or two sides with aluminum, copper, gold, indium tin oxide or other metals and alloys.

Patterned Materials are produced by laser etching our special thin film coatings. Any pattern that can be drawn on paper can be reproduced in the thin film coating. Sheet sizes up to 24 inches x 48 inches or rolls up to 48 inches wide can be patterned.

DEPOSITION MATERIALS

All metals, alloys, semiconductors and most dielectrics can be vacuum deposited onto a variety of substrates. The depositions can be controlled to a specified thickness, optical density, transmission, absorptance, emittance, reflectance or electrical resistance. Continuous process monitoring and thorough testing assure that all materials produced are highest quality and meet specified requirements.

SUBSTRATE MATERIALS

Flexible films ranging from 0.9 microns to 175 microns (0.000036 inch to 0.007 inch) are processed. Size can range from a few square inches up to 48 inch wide continuous rolls.

Rigid substrates up to 24 inches in diameter or diagonal can be coated with thin film materials.

PRESSURE SENSITIVE ADHESIVES

Acrylic pressure sensitive adhesive can be applied to flexible film substrates to provide for easy attachment to other surfaces. Tapes can be produced in widths from 0.5 inch up to 48 inches wide.

MANUFACTURING RESOURCES

Our thin film vacuum deposition tanks are constructed of stainless steel. They are cryo-pumped, clean, oil free and capable of pumping to 1 X 10^{-7} torr.

System one can roll coat webs up to 24 inches wide with three-cathode capability.

System two can roll coat webs up to 48 inches wide with six-cathode capability.

The main deposition drums may be heated or cooled. The deposition systems consist of planar sputtering cathodes capable of DC and pulsed DC magnetron sputtering and AC sputtering. The sputtering supplies include arc suppression equipment to allow easy sputtering of normally difficult materials and reactive processes. Any or all of the systems can be operated simultaneously. Virtually any metal, alloy, semi-conductor, metal oxide or nitride can be deposited in any combination.

LABORATORY ANALYSIS

Our laboratory is equipped with up-to-date test instruments to verify the specified requirements of the deposited materials. We can test the films for transmittance, reflection, optical density, absorptance, emittance, coating thickness, electrical resistance, accelerated weather-ability, atomic oxygen resistance, flexibility, temperature cycling and burst strength.

If you have a need for vacuum metalizing or thin film coated materials, give us a call. We offer **INNOVATION, PRECISION, HIGHEST QUALITY** and **PROMPT DELIVERY.**

Testing Capabilities

Astral Technology has a well equipped test laboratory to ensure the highest quality in production materials. Tests routinely performed are:

Solar absorptance per ASTM E903 and ASTM E490
Room temperature emittance per ASTM E408
U.V. exposure per ASTM D4329
Film adhesion per ASTM D3359
Optical transmission and reflection from 190nm to 16um
Optical density
Optical haze
Thin film physical thickness
Electrical resistivity
Atomic oxygen resistance
Flex testing
Burst testing
Bake testing
Tensile testing
Peel testing

In-house equipment consists of:

Perkin Elmer Lambda 19 UV/Vis/NIR spectroreflectometer
Perkin Elmer Lambda 3 UV/Vis spectrophotometer
Perkin Elmer 1310 Infrared spectrophotometer
Beckman DK2A spectroreflectometer
Tobias Transmission Densitometer
Monroe Electronics Model 272 Resistivity Meter
Macbeth Model TD504 Densitometers
Hazegard Model XL-311 hazemeter
Device and Services Company Model AE emissometer
Dektak Model IIA microprofilometer
Keithley Model 2000 8 digit VOM
Delcom Model 717 noncontact conductance monitor
Delcom Model 727R noncontact conductance monitor
Q-Panel Model QUV accelerated weatherometer
LFE Model PDS/PDE R.F. plasma asher
AND Model HM-202 and Mettler ME22 microbalances
Instron Tensile Tester Model 4201
Despatch oven

Additionally, both deposition systems are equipped with quadrapole mass spectrometers and Ocean Optics UV/Vis spectrometers.

Astral
Technology
Unlimited, Inc.

1611 Riverview Lane • Northfield, Minnesota 55057
Phone 507/645-0935 • Fax 507/663-8807
Toll Free 888/244-0664 • Email atu@clear.lakes.com
Website www.astraltechnology.com