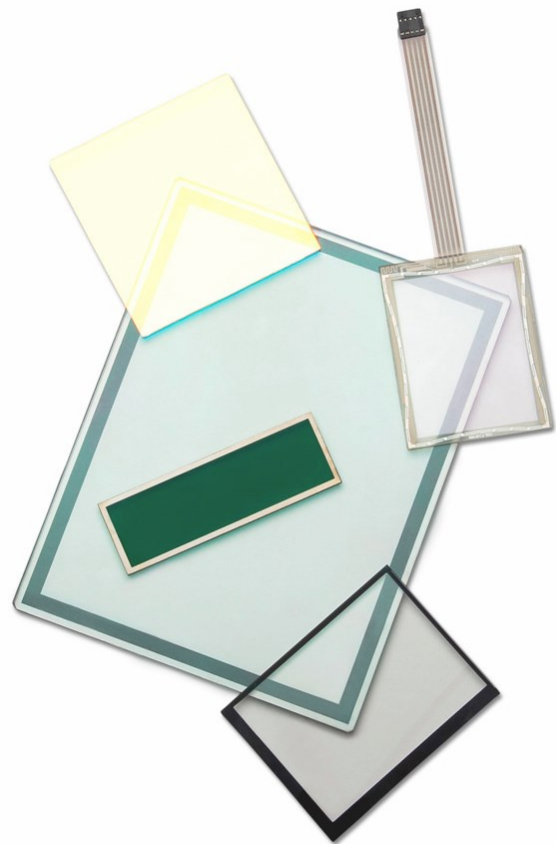


**High Performance Thin Film Optical Coatings
Technical Capabilities**

03/23



High Performance Thin Film Optical Coatings Technical Capabilities

11/22

ZC&R Coatings for Optics, an Abrisa Technologies Company provides high-efficiency coatings for industrial, commercial, and opto-electronic applications. The broad selection of coatings is applied via electron beam and ion-assisted electron beam deposition to influence and control reflectance, transmittance, absorbance and resistance. From high performance Indium Tin Oxide (ITO) and Index-Matched Indium Tin Oxide (IMITO) coatings to patterned optics as well as Anti-Reflective (AR) and anti-glare glass, ZC&R's expert engineering team can deliver coatings to your detailed specifications. We provide coatings and components from 200nm to 20 microns, from the ultraviolet (UV) to the far infrared (IR). Additional thin film optical coating products include front and back surface mirrors, dichroic filters, band pass color filters, Anti-Reflective (AR), beam splitters, metal coatings, precision hot mirrors, cold mirrors, neutral density filters, and IR and UV filters.

Capabilities Overview

- Custom Design and Engineering - (Page 3)**
- Coating Chamber - (Page 3)**
- Substrate Size and Shape Specifications - (Page 3)**
- Measurement and Inspection - (Page 3)**
- Patterning - (Page 4)**

Coatings Capabilities

- CleanVue™ PRO - (Pages 5-7)**
 - PRO-AR399 UV Outdoor Version
 - PRO AR-399 Indoor Version
- Anti-Reflective (AR) Coatings - (Pages 8-9)**
 - Standard
 - Custom
- Transparent Conductive Coatings - (Pages 9-10)**
 - Indium Tin Oxide (ITO)
 - Index-Matched Indium Tin Oxide (IMITO)
- Heat Control - (Pages 11-16)**
 - Hot Mirror Filters
 - Cold Mirror Filters
- UV Filters - (Pages 17-18)**
 - Blocking
 - Blacklite™
 - 470 Short Wave Pass (SWP)
- Dichroics and Color Correction Filters - (Pages 19-22)**
- Wavelength Selection Filters - (Pages 23-24)**
 - Long Wave Pass (LWP)
 - Short Wave Pass (SWP)
 - Band Pass
 - Notch
- Beam Splitters - (Pages 25-27)**
 - Plate (Standard & Polarizing)
 - Cube (Standard & Polarizing)
- Mirrors and Metals - (Pages 28-29)**
 - Dielectric, Metal, Standard, and Custom
- Neutral Density Filters & Dark Mirrors - (Page 30)**
- Infrared (IR) Filters - (Page 31)**
 - Covert
 - Semi-Covert
 - Blackeye



High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Capabilities Overview

Custom Design and Engineering

- Full team of experienced design and manufacturing engineers collaborate to optimize a design for your custom application.
- Design team utilizes a well calibrated computer model that is constantly updated to ensure accuracy of designs.
- Custom coatings designed and produced include thousands of prior designs for a wide variety of applications.
- Extensive history producing coatings for special durability requirements including commercial and military grade specifications.

Coating Chambers

- Depositions are produced in a series of custom designed coating chambers.
 - Chamber sizes range from 32" up to 73" diameter.
 - Coatings are precisely controlled using a combination of optical and crystal quartz monitoring techniques.
- Ion-assisted deposition (IAD) is a key component in producing durable coatings. IAD allows high quality coatings to be manufactured in each of ZC&R's 36", 48", 64" and 73" coating chambers.
- Using four 24" and 27" diameter substrates in each of our larger coating chambers creates a competitive advantage for our customers. Large area substrates and higher quantity work are handled efficiently. Tooling is also available for substrates up to 29" in diameter.

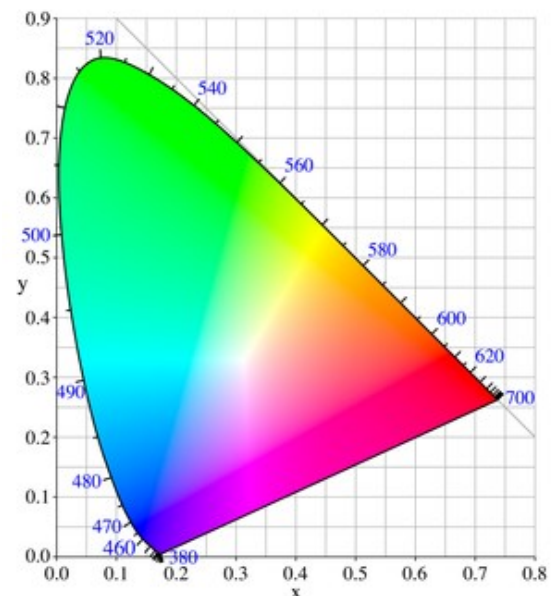
Substrate Size and Shape Specifications

- Small sizes - down to 0.1"
- Large sizes - standard sizes up to 27" in diameter and custom sizes up to 36" in diameter
- Thin substrates - as thin as 70 microns
- Thick substrates - up to 6" in thickness
- Lenses, flats, blocks, wedges, and fibers

Measurement and Inspection

- Spectrophotometers - can measure 200nm up to 20 μ m wavelength in transmission and reflection
- Four-point probes - measures sheet resistance for transparent conductive and metal coatings
- Temperature/humidity chamber - environmental testing per MIL-C-675C and similar specifications
- Colorimetry - precision measurement via spectrophotometer for chromaticity/brightness and color temperature
- Laser power - laser-damage threshold via national laboratories and commercial testing facilities
- Abrasion and adhesion - performed per MIL-PRF-13830B and ISO Specifications
- Salt solubility and salt spray fog - performed per MIL-C-14806A and similar specifications
- Dust and fungus - performed per MIL-C-14806A

Chromaticity Diagram



High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Patterning

ZC&R takes advantage of a variety of techniques when producing patterned coating including shadow masking, photolithography, and printing. Each technique provides a set of cost and performance advantages.

- **Shadow Masking** - ZC&R works with multiple precision mask fabricators to create custom shadow masks. These masks are interposed between the coating source and the substrates during deposition. The shadow mask is used to block coating in areas of the substrate that should be left uncoated. Shadow masking is a lower cost technique that provides for feature size as well as small size features down to 0.020".
- **Photolithography** - High precision patterning can be achieved using photoresist and lift-off or etching. Feature sizes from 5µm to 20µm can be achieved depending on the coating type required.
- **Printed Etching** - Printed etchants are typically used to selectively remove coating to expose conductive layers for electrical contact. A suite of printing systems are used to achieve feature sizes as fine as 0.025". Printed etchants can also be used to remove all coated layers in a pattern with a finer resolution of 0.010".

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Clear Protective Coatings for Coated and Uncoated Glass and Ceramics

The CleanVue™ PRO Series of protective, repelling and oleophobic products are optical abrasion resistant coatings that repel dirt, dust, water, grease and oil to enhance display glass performance and longevity. The resulting coated surfaces are easy-to-clean and maintain, do not stain, allow repeated removal of fingerprints, all while maintaining their optical properties.

The PRO-AR399 is a severe abrasion resistant coating from this series, with anti-reflective performance of < 0.5% photopic reflectance. It is ideal for harsh and heavy use environments and enhanced glass performance and longevity.



No Coating

PRO-AR399 Coated

PRO-AR399 Key Benefits include:

- **Optically Clear:** Provides mechanical protection and repelling properties while achieving < 0.5% photopic reflection and high throughput.
- **Resistant to Severe Abrasion and Scratches:** Low coefficient of friction makes it rugged and durable, protecting the surface from scratches even in harsh or frequent use environments.
- **Easy-to-Clean:** Non-stick surface resists picking up dust and dirt contamination from the surrounding environment and is easy to clean and maintain.
- **Fingerprint & Smudge Resistant:** Oil resistant (Oleophobic) coating reduces adherence of finger-prints and smudges to help maintain pristine image quality even after repeated cleaning.

Applications:

The CleanVue™ PRO Series by Abrisa Technologies is ideal for industrial and commercial needs of OEMs (original equipment manufacturers) and CMs (contract manufacturers) where glass as soda-lime float, Borofloat®, mixed alkali silicate or fused silica are specified in heavy use or harsh environments. CleanVue™ PRO products can be applied to substrates as thin as 0.2mm, and thicker than 100mm.

Typical applications include:

- LCD cover glass
- Vehicular instrument control panels
- Control room display panels
- Projected capacitive (PCAP) touch screens
- Portable handheld devices
- Industrial equipment control panels
- Biometric measurement devices
- Public space and retail digital signage
- Teleprompter and projector optics
- Virtual reality devices
- In-flight and vehicular entertainment screens
- Indoor kiosks and dispensers

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Clear Protective Coatings for Coated and Uncoated Glass and Ceramics (*cont.*)

CleanVue™ PRO Series PRO-AR399 Performance Testing:

PRO-AR399 has been tested* in a controlled environment in order to demonstrate its ability to protect the surface of a glass component from damage or degradation caused by frequent handling and cleaning or by use in harsh environments.

Test Conditions for PRO-AR399: Test results are characterized by the retained water contact angle (WCA) after each test as a percentage of its WCA before each test. Testing included thermal cycling, abrasion and salt solubility testing. Performance was also compared to that of a commercially available industry standard alternative tested under the same test conditions.

- **Optical Performance:** When compared to the industry standard alternative with a broad band average Reflection of < 0.5%, **PRO-AR399** showed superior performance, and post testing, exhibited no measurable degradation of optical performance for reflection or transmission.
- **Thermal Performance:** **PRO-AR399** showed a <5% change in its WCA over 400 hours of elevated temperature of 121°C. During heating/freezing cycles (4 hrs at 71°C followed by 4 hrs at -54°C) it again showed negligible change in WCA after 4 cycles.
- **Mechanical Performance:** **PRO-AR399** was subjected to a number of mild to harsh abrasion tests to demonstrate robustness.
 - **Cheesecloth Abrasion Testing:** per ISO 9211-4: After 500,000 cycles, **PRO-AR399** retained > 95% of its CWA compared to the alternative which retained < 75% of its CWA.
 - **Eraser Severe Abrasion Testing:** (30cpm, 2.2lb wt) per MIL-C-675C: **PRO-AR399** out-performed the industry standard sample by retaining >90% of its WCA after 40 cycles, compared to the alternative's < 80% WCA under the same conditions.
 - **Steel Wool Extra-Severe Abrasion Testing:** (60cpm, 2.2lb wt, 0000 steel wool). Only the **PRO-AR399** maintained its original high CWA level performance for well over 12,000 cycles, out-performing the industry alternative which had dropped to less than 70% CWA by 8000 cycles .
- **Salt Solubility Testing:** (per MIL-PRF-13830B paragraph C.4.5.7): **The PRO-AR399** sample showed no performance degradation after 72 hours of salt solubility testing.

The PRO-AR399 is a more rugged and durable protection solution than the industry standard.

Abrisa Technologies' extensive testing of **CleanVue™ PRO Series PRO-AR399** concludes that the reflectance, transmittance, oleophobic and hydrophobic (water-repelling) and severe abrasion resistance performance of the **CleanVue™ PRO** product is superior to the performance of the industry standard alternative product and able to maintain its CWA performance for >12,000 cycles of severe steel wool abrasion testing, over twice that of the alternative.

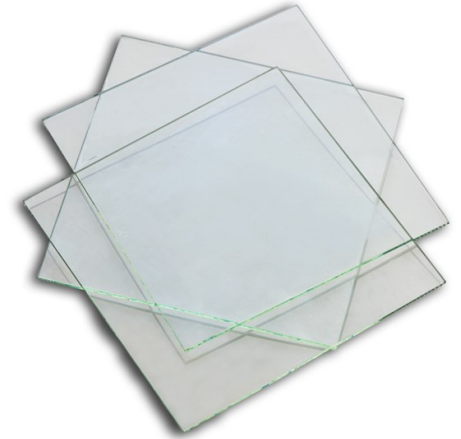
High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

Anti-Reflective (AR)

These coatings are all dielectric single or multi-layers and are designed for low reflectance and high transmittance in the UV, visible, and near IR spectral bands.



Features

- High transmittance
- Low reflectance
- Operating temperature of $\geq 300^{\circ}\text{C}$ (typical)
- Durable and easy-to-clean

Specifications: (standard)

Substrates

- Soda lime float glass
- Borofloat[®] Borosilicate
- Water white float glass
- Polished and drawn technical glass materials such as BK7 fused silica and Eagle XG
- IR materials such as silicon, zinc selenide, and germanium
- Crystalline materials such as CaF₂ and crystal quartz

Thicknesses - range from 0.1mm to over 25.4mm and thicker

Reflectance - as low as 0.05% depending upon wavelengths covered

Transmittance - typically very high. Contact us for specific values for each substrate material

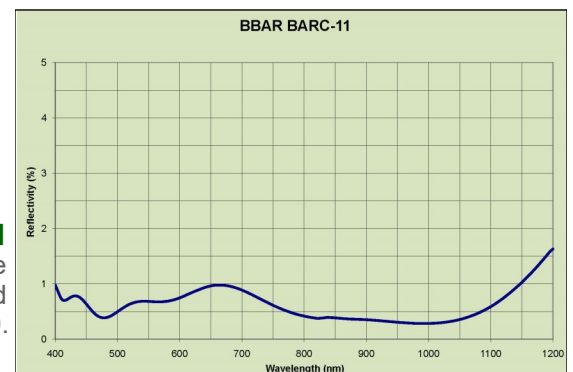
AR coatings from ZC&R meet the requirements of MIL-C-675C, MIL-C-14806A, and MIL-C-48497A. AR Coatings are often crucial components in optical systems with multiple lenses or other optics where the maximum possible light energy is needed. AR coatings help to produce brighter images while reducing the intensity of ghost images which may otherwise be produced in optical systems having multiple reflecting surfaces.

Custom and standard AR coatings commonly deposited by ZC&R are generally separated into two groups. The first group is made up of AR coatings that target one or more broad wavelength bands. Our BARC coatings are examples of this group.



BBAR BARC-5 High Efficiency Coating

This high efficiency broadband anti-reflective coating reflects less than 0.5% average from 425-675nm. Higher performance specifications are also available. Standard & custom coatings are available for refractive indices of 1.46-1.90.

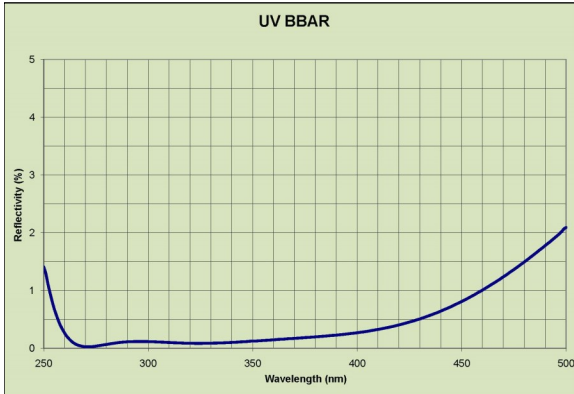


BBAR BARC-11

This broadband coating provides a low level of reflectance across a wide spectrum from 400-1100nm, reflecting less than 1.0% average. Standard and custom coatings are available for refractive indices of 1.46 to 1.90.

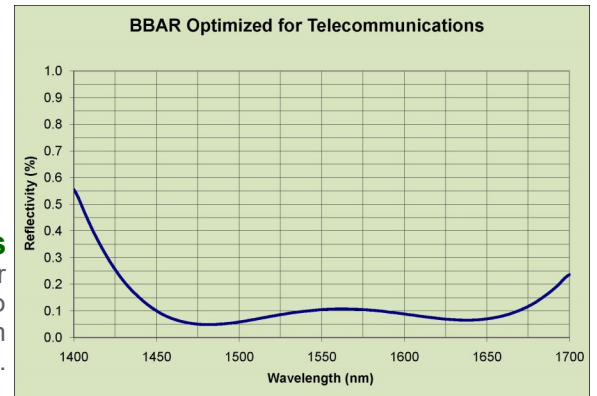
High Performance Thin Film Optical Coatings Technical Capabilities

Anti-Reflective (AR) - continued



UV BBAR

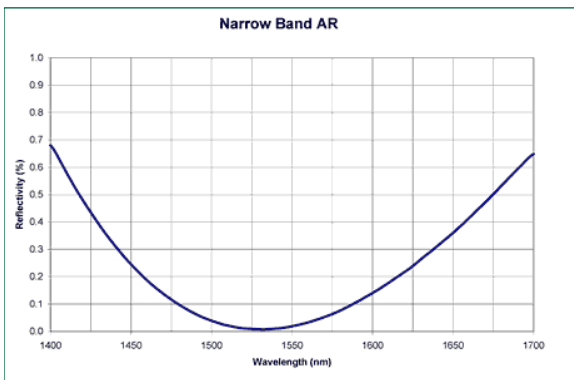
This broadband AR coating is particularly designed for the ultra-violet region. It provides a low level of reflectance less than 0.5% average from 275-425nm. Standard & custom coatings are available for refractive indices of 1.46-1.90.



BBAR Optimized for Telecommunications

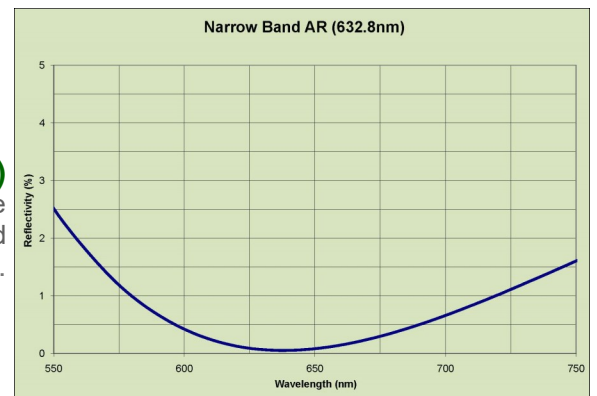
This broadband AR coating is particularly designed for telecommunication applications. It provides a low level of reflectance to less than 0.25% average from 1450-1650nm. Standard & custom coatings are available for refractive indices of 1.46-1.90.

The second group of AR coatings, V-coating target one or more narrow wavelength bands. V-coats are used to target a single wavelength such as 632.8nm or 532nm, or a single very narrow band of wavelengths.



Narrow Band AR (nominally centered @ 1550nm)

This narrow band AR is an excellent coating for targeting a single wavelength or very narrow band of wavelengths at or near 1550nm. Standard < 0.25% and high performance < 0.05% reflectivity specifications are available.



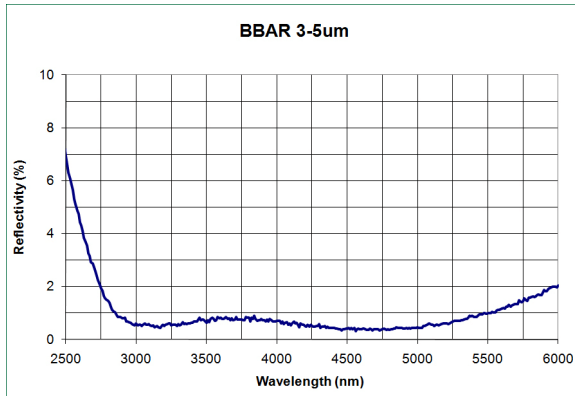
Narrow Band AR (nominally centered @ 632.8nm)

This narrow band AR is an excellent coating for targeting a single wavelength or very narrow band of wavelengths. Standard < 0.25% and high performance < 0.05% reflectivity specifications are available.

High Performance Thin Film Optical Coatings Technical Capabilities

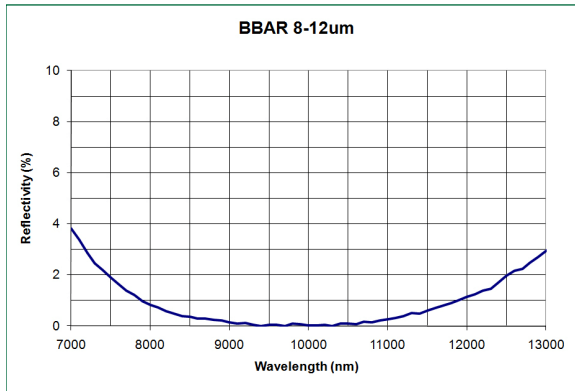
11/22

Anti-Reflective (AR) *continued*



IR-BBAR 3-5 Microns

This AR coating provides a low level of reflectance for the mid-infrared spectrum (3000nm to 5000nm). Band averaged reflectance is less than 1.0% at normal incidence.



IR-BBAR 8-12 Microns

This AR coating provides a low level of reflectance for the far-infrared spectrum (8um to 12um). Band averaged reflectance is less than 1.0% at normal incidence.

Custom AR Coatings - Often, our customers need a custom AR coating that is tailored to meet their specific requirements. The ZC&R Coatings for Optics division of Abrisatechnologies has developed thousands of AR coatings to fulfill such needs. If you have a custom AR requirement just let us know, and we will be happy to submit a design curve for your review.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

Transparent Conductive Coatings

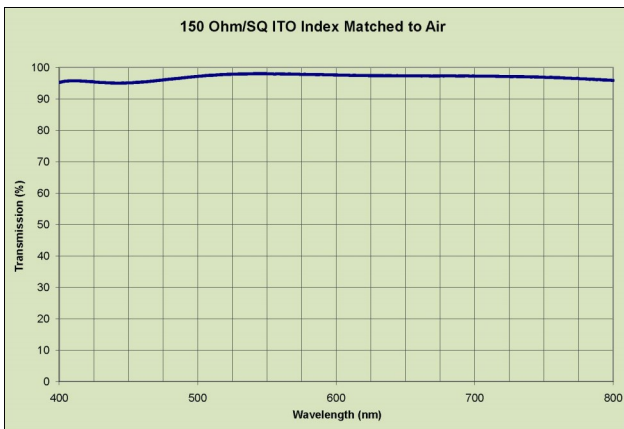
Indium Tin Oxide (ITO) & Index-Matched Indium Tin Oxide (IMITO)

Transparent conductive coatings are very often used in electro-magnetic shielding, electrical heating, and cutting edge display applications. ZC&R uses the coating material indium tin oxide (ITO) which provides for high transmitting durable coatings.

Often, ITO coatings are used in contact with materials other than air. ZC&R often designs and produces ITO coatings designed specifically to be used next to materials such as liquid crystal, cements, index oils, and various other materials. ITO coatings that have been under-coated or over-coated to be index matched to a particular material such as liquid crystal can have very low reflectances.

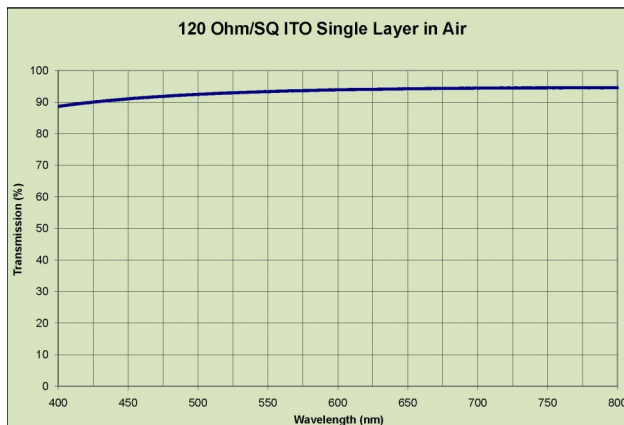
One determining factor as to how low a reflectance can be achieved is the sheet resistivity specification. Thicker ITO layers yield lower sheet resistivities but generally result in higher reflectances. Sheet resistivities as low as 5 to 10 ohms/sq and as high as a few thousand ohms/sq can be achieved. One common thickness of ITO, 100 angstroms, yields approximately 450 ohms/sq.

ZC&R has a great deal of experience coating ITO and index-matched ITO and we would be happy to review any specification requirements you may have, and work with you to determine what can be achieved using ITO coatings for your particular application.



150 ohms/sq Index-Matched ITO in Air

Index-matched ITO (IMITO) provides a combination of low resistivity of 150 ohms/sq and extra transmission in the visible spectrum (400-700nm) with an average transmittance of 94%.



120 ohms/sq ITO Single Layer in Air

This single layer ITO coating provides an average transmittance of 90% over the visible spectrum (400-700nm) with resistivity of 120 ohms/sq. Standard tolerance for sheet resistivity is $\pm 20\%$. Higher or lower resistivities are available upon request.

ZC&R Coatings for Optics

An Abrisa Technologies Company • (800) 426-2864

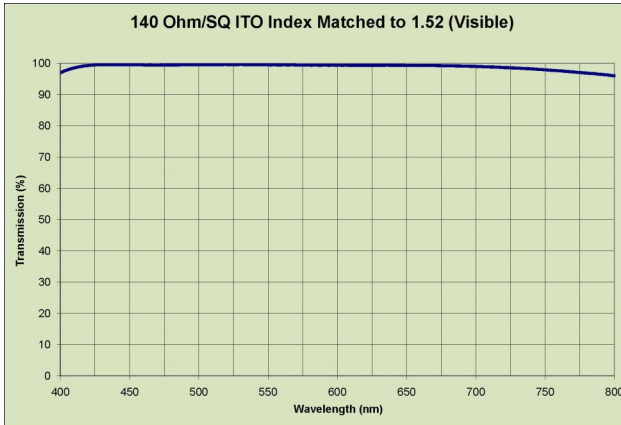
info@abrisatechnologies.com • www.abrisatechnologies.com

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

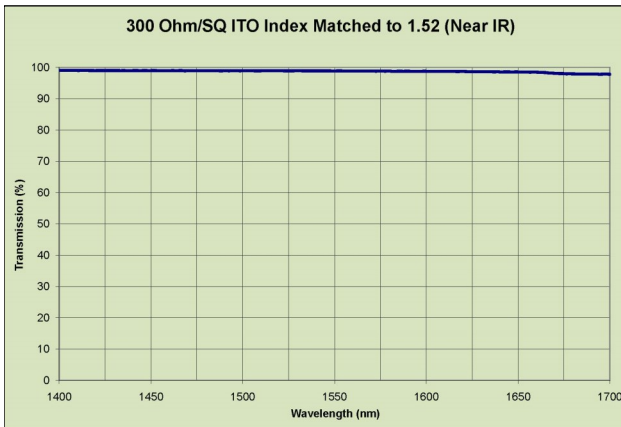
Coatings Capabilities

Indium Tin Oxide (ITO) & Index-Matched Indium Tin Oxide (IMITO) - *continued*



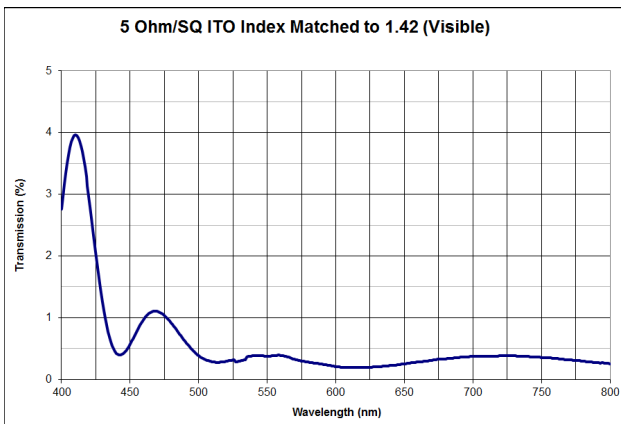
140 ohms/sq ITO Index-Matched to 1.52 (Visible)

This index-matched ITO provides very high transmission average of 97% from 425-675nm, with resistivity of 140 ohms/sq. This coating is index matched to 1.52. Higher or lower resistivities and matching custom indices and multi-layer structures are available on request



Index-Matched ITO for Telecommunications C&L Bands

This index-matched ITO provides very high transmission average of 97% from 1425-1650nm, with resistivity of 300 ohms/sq. This coating is index matched to 1.52. Higher or lower resistivities and matching custom indices and multi-layer structures are available on request.



5 ohms/sq ITO Index-Matched Low Reflectance EMI Shielding for Displays

Photopic* reflectance specified to be less than 1.0% for angles near normal incidence. Typical photopic transmittance is approximately 95%. This coating is designed to be immersed in a laminate. Sheet resistance less than 5 ohms/sq.

* Human eye response in daylight or similar conditions.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

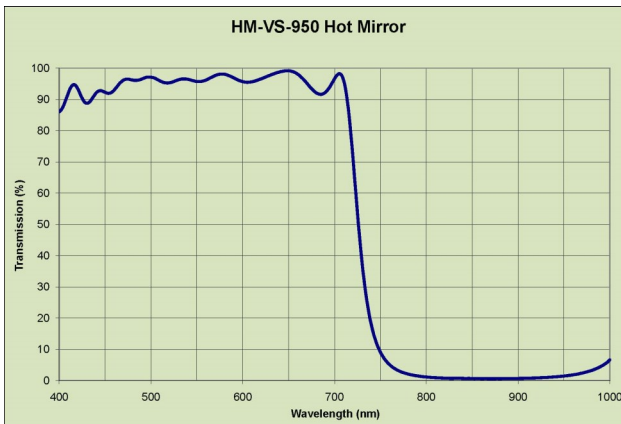
Heat Control - Hot Mirror Filters

A hot mirror is in essence a thin film coating applied to substrates in an effort to reflect infra-red radiation either as a means to harness the reflected wavelengths for an application or to remove them from an application.

Specifications:

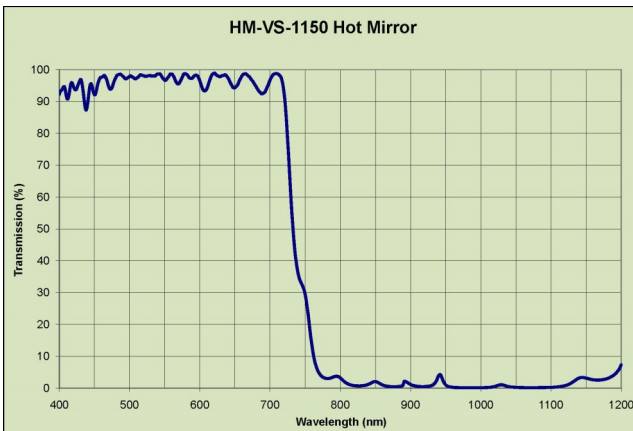
Substrate: Borofloat[®] - Borosilicate and other standard glass substrate materials
Thickness: 1.1mm, 1.75mm, and 3.3mm
Size: Up to 24" in diameter

HM-VS-950 Hot Mirror



Hot mirror filters transmit the visible spectrum and reflect the infrared at normal incidence. The average transmittance is specified to be more than 93% from 425 to 675nm and average reflectance is more than 95% from 750 to 950nm. Custom angles of incidence can be designed to specification.

HM-VS-1150 Hot Mirror



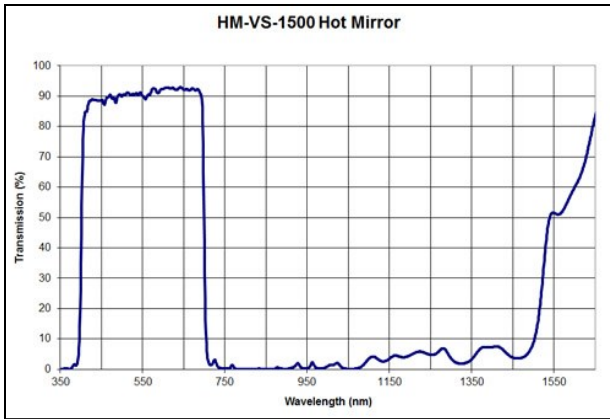
These hot mirror filters transmit the visible spectrum and reflect the infrared at 0 degrees. The average transmittance is more than 93% from 425 to 675nm. The average reflectance is more than 95% from 750 to 1150nm. Custom angles of incidence can be designed to specification.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

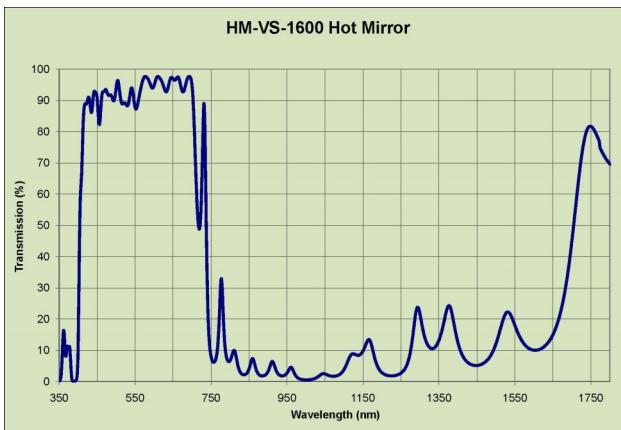
Coatings Capabilities

Heat Control - Hot Mirror Filters - *continued*



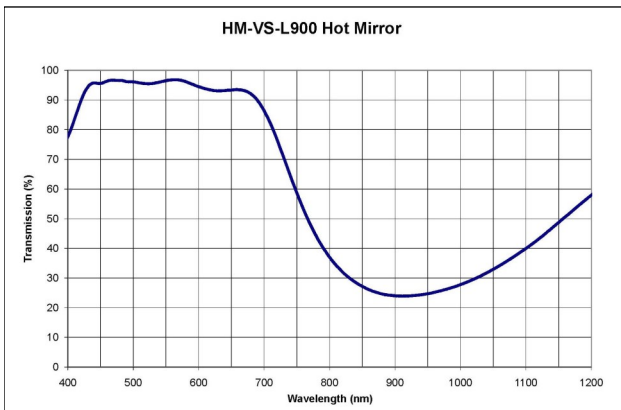
HM-VS-1500 Hot Mirror

Extreme performance hot mirrors offer enhanced UV blocking.
Average T \geq 85% 420-680nm
Average T \leq 1% 200-380nm
Average R \geq 95% 730-1500nm



HM-VS-1600 Hot Mirror

Extended Hot mirror filters transmit the visible spectrum and reflect the infrared at normal incidence. The average transmission is specified to be more than 85% from 425-675nm and average reflectance is more than 90% from 750-1150nm and 80% from 1150-1600nm. Custom angles of incidence can be designed to specification.



HM-VS-L900 Hot Mirror

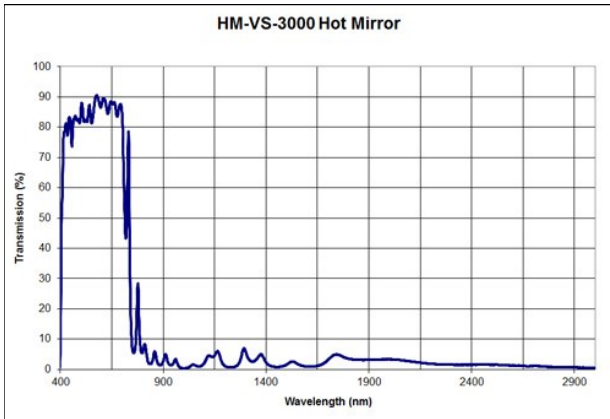
These hot mirror filters transmit the visible spectrum and reflect the infrared at normal incidence and offer reliable solutions for commercial applications.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

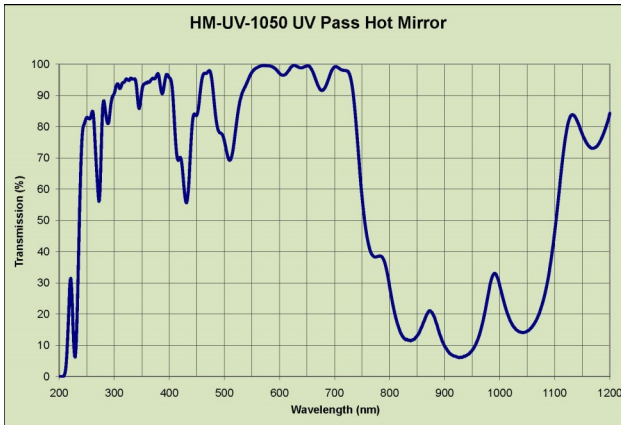
Coatings Capabilities

Heat Control - Hot Mirror Filters - *continued*



HM-VS-3000 Hot Mirror Filter

Our HM-VS-3000 filter combines reflectance and absorptance to block a very wide band in the infrared while maintaining good visible transmittance.



HM-UV-1050 UV Pass Hot Mirror

UV Hot mirror filters are specially designed to transmit more than 80% on average from 245-460nm and reflect more than 70% in average from 800-1050nm at normal incidence. Custom angles of incidence can be designed to specification.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

Heat Control - Cold Mirror Filters

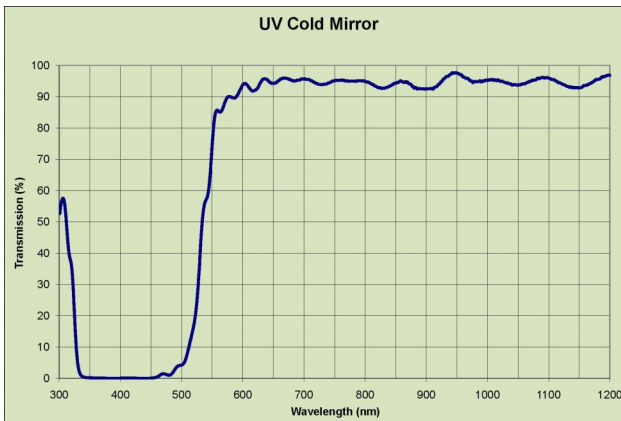
ZC&R cold mirrors reflect visible energy and transmit the infrared (heat energy). The cold mirrors are vacuum deposited and all dielectric.

Features:

- Operating Temperature $\geq 300^{\circ}\text{C}$ (typical)
- Durable and Easy-to-Clean

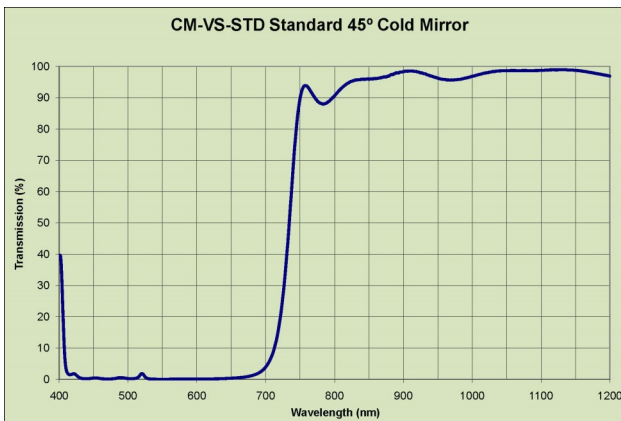
Specifications:

Substrate: Borofloat[®] - Borosilicate and other standard glass substrate materials
Thickness: 1.1mm, 1.75mm, and 3.3mm
Size: Up to 24" in diameter



UV Cold Mirror

This cold mirror is specially designed to reflect more than 95% average of ultra-violet rays from 350-450nm and transmit more than 90% average 550-1200nm at 45 degrees angle of incidence. Custom angles of incidence can be designed to specification.



CM-VS-STD 45 Degree Cold Mirror

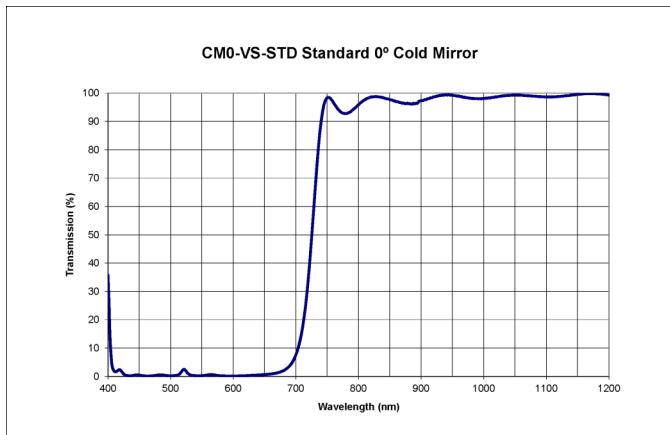
This cold mirror is designed to operate at a 45 degree angle of incidence. It reflects the visible spectrum and transmits the heat (infrared). The average reflectance is greater than 95% from 425-650nm. Transmittance is more than 85% average from 800-1200nm. These filters are commonly coated for normal incidence applications as well (see CM0-VS.-STD) Custom angles of incidence can be designed to specification.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

Heat Control - Cold Mirror Filters - *continued*



CM0-VS-STD 0 Degree Cold Mirror

This cold mirror filter is designed to operate at 0 degrees angle of incidence. It reflects the visible spectrum and transmits heat (infrared). The average reflectance is greater than 95% from 425-650nm. Transmittance is more than 85% average from 800-1200nm. These filters are commonly coated for normal incidence applications as well. Custom angles of incidence can be designed to specification.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

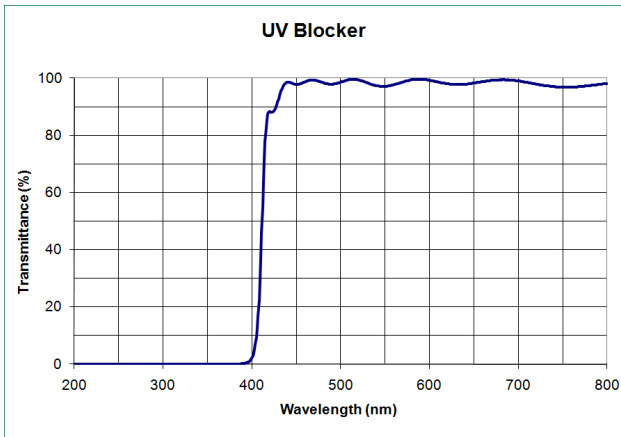
Coatings Capabilities

UV Filters - Blocking, Blacklite™ and 470 Short Wave Pass (SWP)

Managing ultraviolet (UV) light exposure is critical in a wide variety of applications including some necessary to life. ZC&R has a several standard coatings designed to manage UV light for a wide variety of applications. Overexposure to UV can cause skin and eye damage requiring windows and other glass surfaces to be used for protection. Similarly, UV exposure can also damage artwork, documents, and other ink based items we might expect to find behind UV blocking glass generally found in museums. On the other hand, there is our need for UV exposure in moderation for processes such as vitamin D synthesis. UV exposure is also used in curing applications, fluorescence microscopy for cellular imaging, and even Blacklite lamps for entertainment venues.

Specifications:

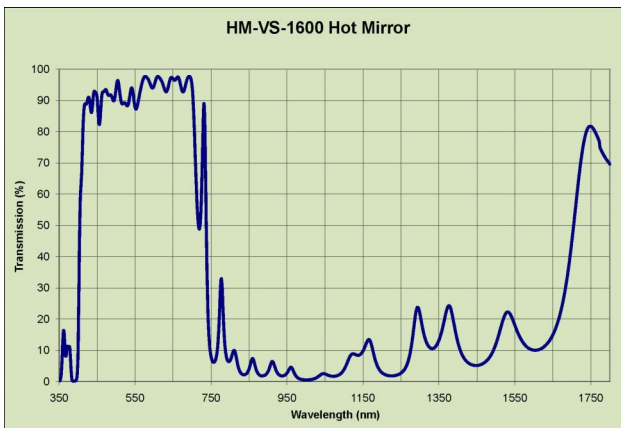
Substrate: Borofloat[®] - Borosilicate and other standard glass substrate materials
Thickness: 0.125" (3.175mm) - custom thicknesses available
Size: Up to 24" (609.6mm) diameter max.



UV Blocking Filters

Our UV Blocker coating is used in a variety of UV sensitive applications. Examples include protection of artwork in museum displays, liquid crystal devices, and UV sensitive optical fibers.

Average T ≤ 1% 200-390nm
 Average T ≥ 90% 430-700nm



HM-UV-1050 UV Pass Hot Mirror

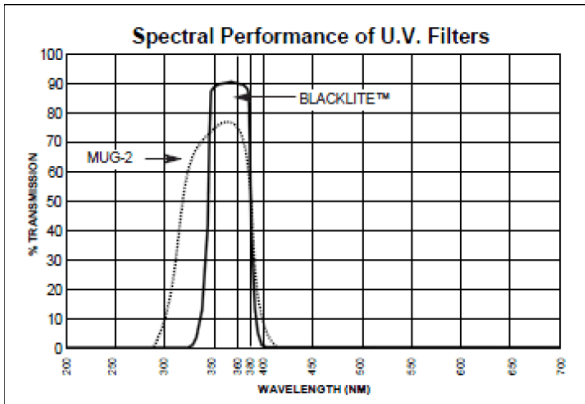
UV Hot Mirror filters are specially designed to transmit more than 80% on average from 245-460nm and reflect more than 70% in average from 800-1050nm at normal incidence. Custom angles of incidence can be designed to specification.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

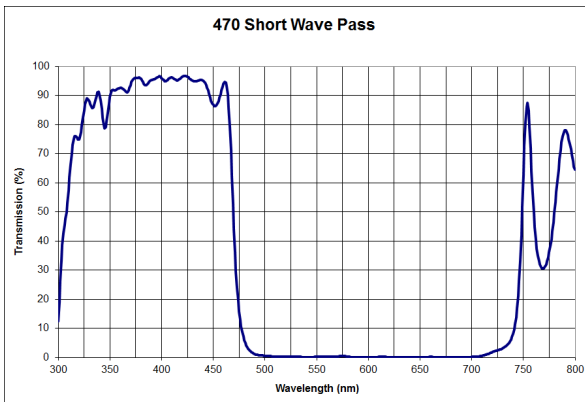
Coatings Capabilities

UV Filters - Blocking, Blacklite™ and 470 Short Wave Pass (SWP) - *continued*



Blacklite™ UV Filters

Blacklite™ filters are all dielectric thin films on borosilicate glass and offer some additional features over MUG-2 filter glass. The transmitted efficiency is superior, which is critical in areas such as forensics, fluorescence and inspection. Because this is a coated filter, rather than an absorption based filter glass, heat produced by the light source is allowed to exit through the filter. This lowers overall system temperature and can extend lamp life. Additionally, in high temperature applications where tempered MUG-2 is not adequate, Blacklite™ may be suitable due to its Borofloat[®] substrate.



470 Short Wave Pass (SWP) Filters

470 SWP filters are often used in fluorescence microscopy and other applications where near UV and blue pump wavelengths are required. Our 470 SWP filter passes an average of 85% of energy from 340nm-450nm wavelengths. Average transmittance from 500nm-700nm is reduced to less than 0.5%. Performance is specified at normal incidence. This coating is typically provided on Borofloat[®] glass but can also be coated onto fused silica or other UV transmissive glass materials.

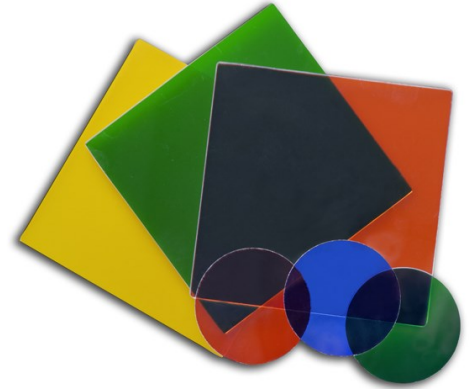
High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

Dichroics and Color Correction Filters

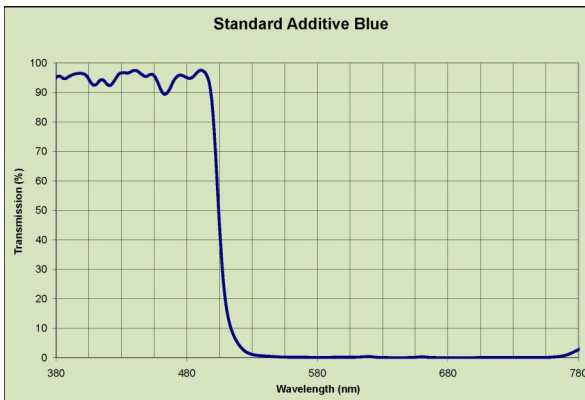
Dichroic color filter coatings are an excellent alternative to dyed plastics and glass when a beam of light must be split into two distinct beams varying by wavelength. Color correction filters alter the overall color of light to achieve a specific color and sometimes to obtain a specific color temperature. Unlike plastic color gels which age and breakdown quickly during use, dichroic filters and color correction filters are designed to stand up to the heat and UV energy in high energy light sources. High energy light sources can also have a damaging effect on dyed glasses as well, due to their heat absorbing nature.



Dichroic and color correction filters have the advantage of reflecting unwanted light instead of absorbing the energy, which allows dichroic filters to be used with much higher intensity light sources up to 550°F.

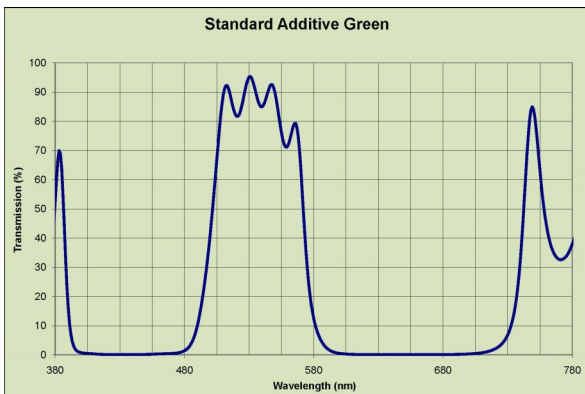
Dichroic color filters are used in a variety of applications including architectural, entertainment, scientific instruments, and engineering. Many industry standard colors have been engineered as dichroic filters.

We have over 160 different colors available. Dichroics are offered from 1.1mm (.043") thick up to 3.3mm (1.28") thick.



Standard Additive Blue

The Standard Additive Blue color coating has an average transmittance more than 85% from 390-480nm, 50% point at 505nm \pm 15nm, and average transmission less than 1% from 540-750nm at normal incidence.



Standard Additive Green

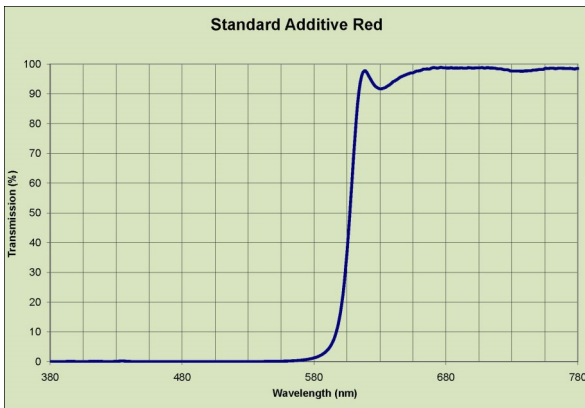
The Standard Additive Green color coating has an average transmittance less than 1% from 400-460nm, 50% point at 505nm \pm 15nm, peak transmission at more than 70%, 50% point at 575nm \pm 15nm and average transmittance less than 1% at 610-710nm at normal incidence.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

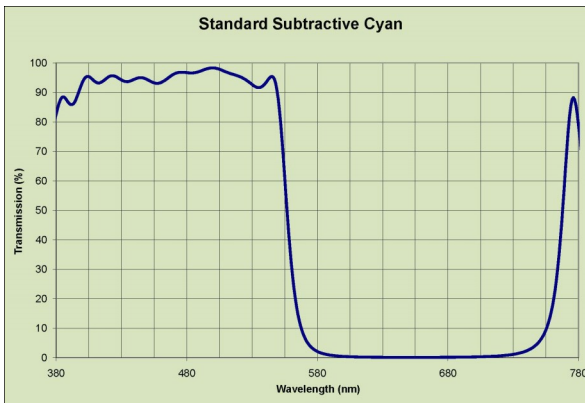
Coatings Capabilities

Dichroics and Color Correction Filters - *continued*



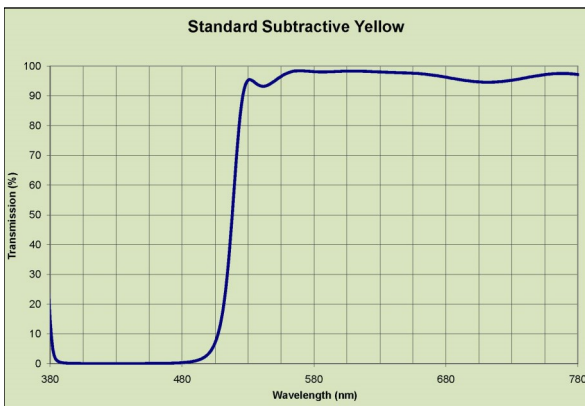
Standard Additive Red

The Standard Additive Red color coating has an average transmittance less than 1% from 390-550nm, 50% point at 605nm \pm 15nm and average transmittance more than 75% from 620-730nm at normal incidence.



Standard Subtractive Cyan

The Standard Subtractive Cyan (Anti-Red) color coating has an average transmittance more than 85% from 400-550nm, 50% point at 590nm \pm 15nm and average transmittance less than 1% from 640-720nm at normal incidence.



Standard Subtractive Yellow

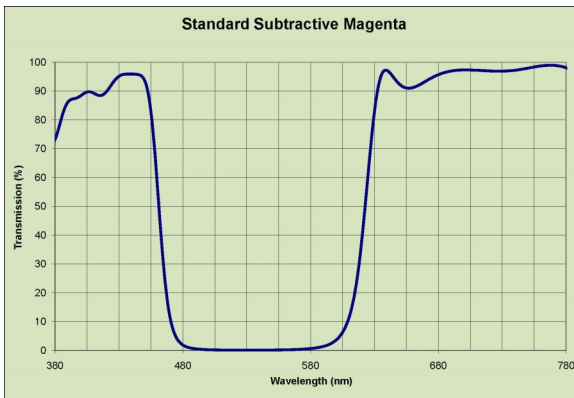
The Standard Subtractive Yellow (Anti-Blue) color coating has an average transmittance less than 1% from 410-475nm, 50% point at 515nm \pm 15nm and average transmittance more than 85% from 550-750nm at normal incidence.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

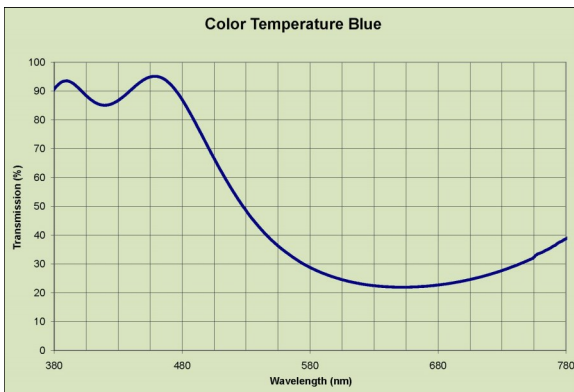
Coatings Capabilities

Dichroics and Color Correction Filters - *continued*



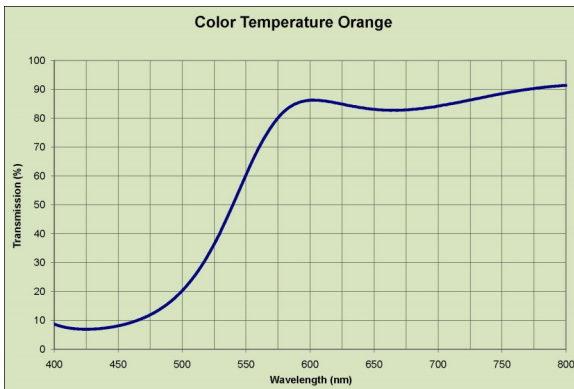
Standard Subtractive Magenta

The Standard Subtractive Magenta (Anti-Green) color coating has an average transmittance more than 80% from 380-470nm, 50% point at 485nm ±15nm, average transmittance less than 1% from 535-565nm, 50% point at 615nm ±15nm and average transmittance more than 80% 655-750nm at normal incidence.



Color Temperature Blue

A variety of standard color correcting filters are available including Color Temperature Blue (CTB). A Full CTB filter converts a 3200K light source to 5500K. Most filters are stocked in 24" diameter x 3.3 mm thick Borofloat[®]. Additionally, CTB filters are available in shades with lesser color temperature shift.



Color Temperature Orange

Another standard color correcting filter is Color Temperature Orange (CTO). A Full CTO filter converts a 5500K light source to 3200K. Most filters are stocked in 24" diameter x 3.3 mm thick Borofloat[®]. CTO filters are also available in shades with lesser color temperature shift.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

Dichroics and Color Correction Filters - *continued*

ZC&R Coatings for Optics has over 160 different standard dichroic colors in stock. These long lasting filters can withstand up to 550°F. These standard dichroics are offered from 1.1mm (.043") thick up to 3.3mm (1.28") thick.

Dichroic Filters

We have over 160 different standard dichroic color in stock. These long lasting filters can withstand up to 550°F. Dichroics are offered from 1.1mm (.043") thick up to 3.3mm (1.28") thick.

Standard dichroics are dyed glass color filters

		Similar to Rosco #
#120	Red	26
#121	Golden Amber	20
#122	Yellow	12
#123	Medium Green	389
#125	Medium Blue	68
#129	Blue Magenta	49
#130	Indigo	59
#131	Pink Amber	03
#132	Cyan	73
#133	Pink	36
#134	Dark Blue	80
#135	Flesh Pink	34
#137	Deep Blue	85
#138	Orange Red	25
#139	Pink Magenta	346
#142	Orange	23
#143	Fire	22
#144	Salmon	42
#145	Pale Pink	34
#146	Light Yellow Green	86
#147	Medium Yellow Green	90
#149	Pale Green	88
#150	Aqua (Turquoise)	95
#151	Straw Amber	15
#153	Pink Peach	02
#154	Medium Dark Blue	69

Absorption Filters

Can be heat treated up to 6" in diameter for added heat resistance, 1/8" thick. If high heat resistance is needed use dichroics.

Similar to Rosco

#201	Red	27
#203	Yellow	10
#205	Pink	38
#206	Deep Green	90
#207	Medium Amber	20
#208	Medium Blue	64
#209	Dark Blue	83
#211	Light Blue	60
#401	Lavender	54
#402	Mercury Vapor Green	3304
#403	Light Green	88

In addition, we carry a number of standard absorption based filter glass materials.

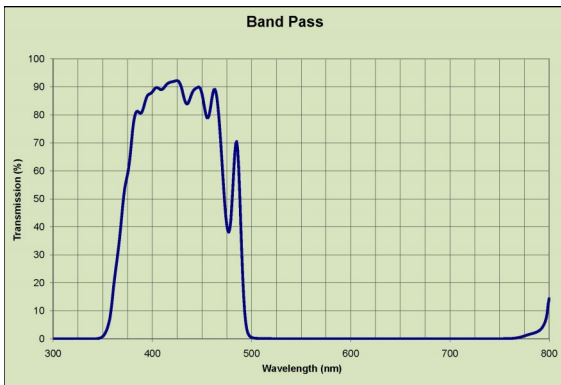
High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

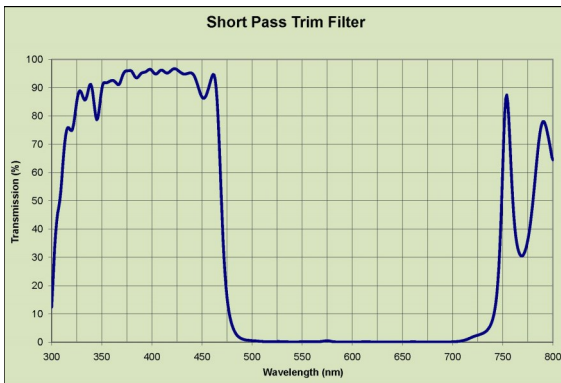
Wavelength Selection Filters - Band Pass, Short Pass, Long Pass, and Notch

Trim filters, also commonly known as cut-off or dichroic filters, are advantageous for a variety of applications. Common uses include optical noise reduction for bar-code readers and wavelength band isolation for fluorescence applications. Trim filters are often used in conjunction with absorptive filter glasses to form band pass filters.



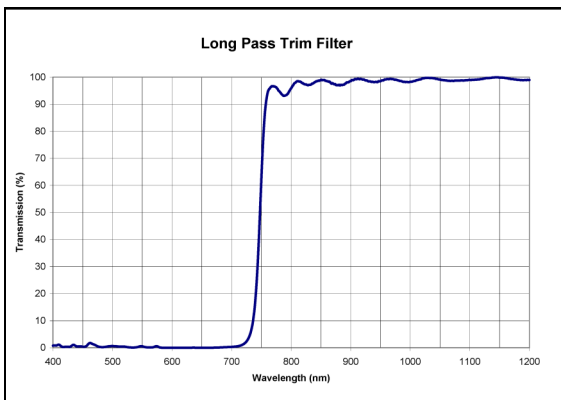
Band Pass Filters

These filter coatings transmit varying wavelength bands, which are determined by two cutoff wavelengths. Filters can be made at any given wavelength from near ultraviolet to near infrared.



Short Wave Pass Trim Filters (SWP)

Short pass filters block a select band of longer wavelengths. This example, short pass filters block a select band of longer wavelengths. short wave pass cutoff filter passes light from 325-450nm and blocks visible light from 500-700nm. It has a 50% point at 470nm \pm 10nm. Custom short wave pass filters are available on request.



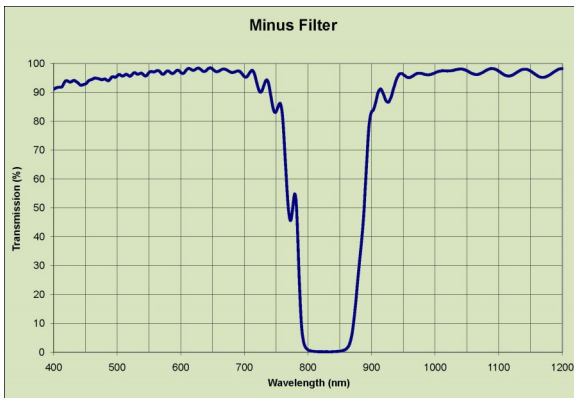
Long Wave Pass Trim Filter (LWP)

Long pass filters block a select band of shorter wavelengths. This example, long wave pass cutoff filter provides average reflectance more than 99% from 400-700nm, 50% cutoff point at 750nm \pm 10nm and 95% transmission from 780-1200nm. Custom long wave pass filters are available on request.

High Performance Thin Film Optical Coatings Technical Capabilities

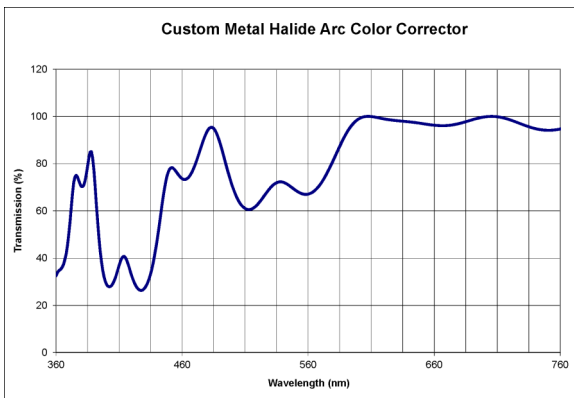
Coatings Capabilities

Wavelength Selection Filters - Band Pass, Short Pass, Long Pass, and Notch - *continued*



Notch (Minus) Filter

Notch filters block a relatively narrow band of wavelengths between shorter and longer pass bands. This example narrow band minus filter has a nominal bandwidth of 110nm with an average reflection of more than 99% over a nominal bandwidth of 30-40 nm. The pass bands have an average transmission of 90%. Custom made minus filters are available on request.



Color Temperature Filter for Metal Halide Lamps

The filter suppresses down the high peak areas in the blue and green that is output by the lamps to have a more level loaded color output response. More white and not as "cold" a color.

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

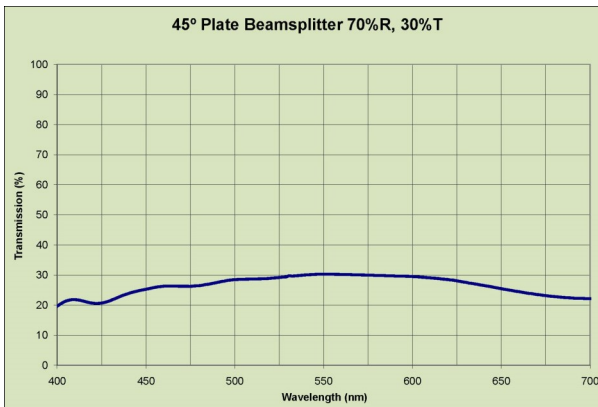
Coatings Capabilities

Beam Splitters - Plate and Cube; Standard and Polarizing

Beam Splitter (BS) is a term used to describe various coatings which divide a beam of light into separate beams. Dichroic filters are often called beam splitters. In this section, we will be describing beam splitters that divide light at each wavelength of interest into two separate beams. These beam splitters are typically designed for an incident angle around 45 degrees from normal.

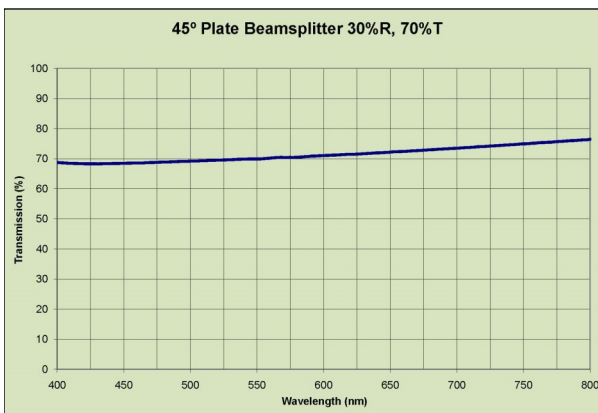
Partially transmitting metals also make very useful beam splitter coatings. Two common metals used for this purpose are Inconel and chrome. Metal beam splitters are often very broad and can cover a much wider spectrum of wavelengths than their dielectric counterparts.

Dielectric coatings as described here have the advantage of being non-absorbing and so allow for greater throughput of energy. These dichroic filters for example, have a dielectric coating that can be used for a 50/50 beam splitter. In contrast, Inconel is limited to 30% transmission and 30% reflection due to the absorption inherent in the metal film. Standard dielectric beam splitter coatings include 30/70, 50/50, and 70/30. We welcome inquiries regarding any custom requirements you may have.



*45-Degree Plate Beam Splitter 70%R, 30%T

This coating reflects 70% and transmits 30% ($\pm 10\%$) from 450-650nm at 45 degrees angle of incidence.



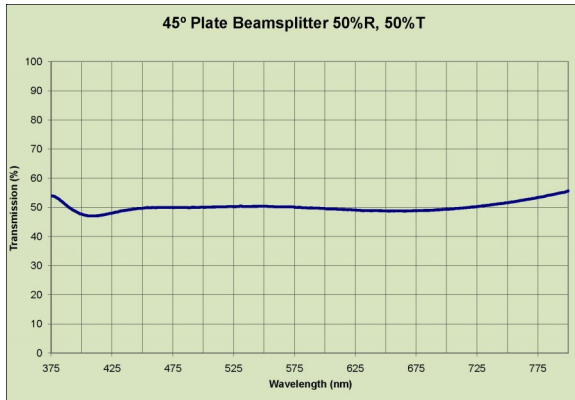
*45-Degree Plate Beam Splitter 30%R, 70%T

This coating transmits 70% and reflects 30% ($\pm 10\%$) from 450-650nm at 45 degrees angle of incidence.

High Performance Thin Film Optical Coatings Technical Capabilities

Coatings Capabilities

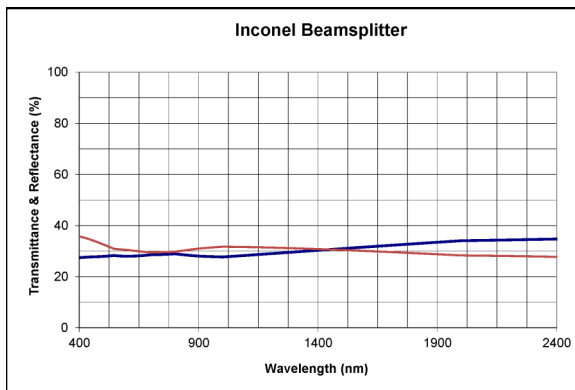
Beam Splitters - Plate and Cube; Standard and Polarizing - *continued*



*45-Degree Plate Beam Splitter 50%R, 50%T

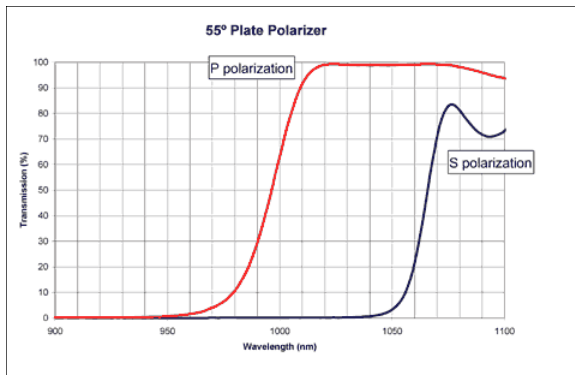
This coating is designed to transmit 50% and reflect 50% ±10% from 425-650nm at 45 degrees angle of incidence.

*Average transmittance and reflectance.



Inconel Beam Splitter

Partially transmitting metals make very useful beam splitter coatings. Two common metals used for this purpose are Inconel and chrome. Metal beam splitters are often very broad and can cover a much wider spectrum of wavelengths than their dielectric counterparts. In this example, a single layer of Inconel with approximately equal reflectance and transmittance is shown.



55-Degree Plate Polarizer

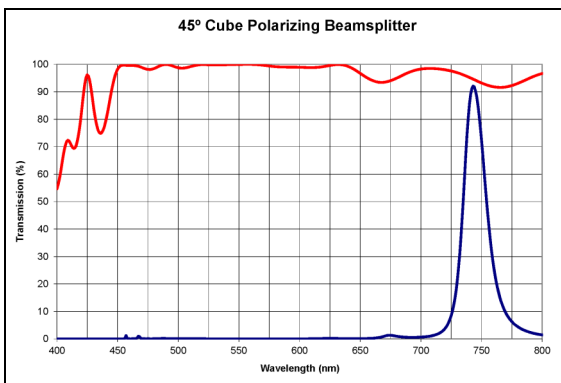
This coating provides greater than 97% transmission of "P" polarized light and greater than 97% reflectance of "S" polarized light at single specified wavelength. Generally the angle of incidence is specified between 45 and 65 degrees.

High Performance Thin Film Optical Coatings Technical Capabilities

Coatings Capabilities

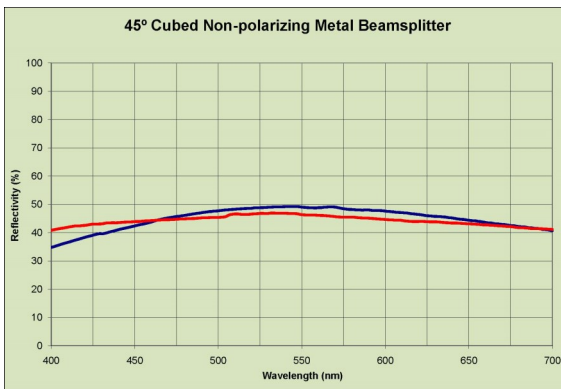
Beam Splitters - Plate and Cube; Standard and Polarizing (cont.)

Cube Beam Splitters - Cube Beam Splitters are especially useful in separating light into component polarizations over a broadband spectra.



45-Degree Cube Polarizing Beam Splitter

Typically higher index glass to maximize polarization separation. This example is designed for a substrate refraction index of approximately 1.80.



45-Degree Non-Polarizing Hybrid Cubed Beam Splitter

This coating has an average transmission of 45% and 45% reflectance from 475-625nm for both “S” and “P” polarizations.

High Performance Thin Film Optical Coatings Technical Capabilities

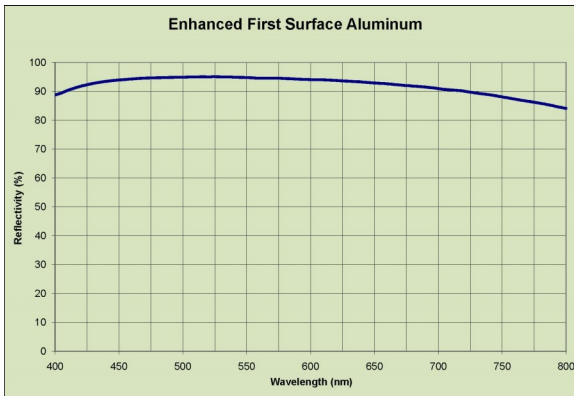
Coatings Capabilities

Mirrors and Metals

Metal mirror coatings are often used in systems where a very broadband reflector or beam splitter is needed. Metal coatings can also be an excellent choice when an economical coating is especially important. Examples of common metal coating applications include telescope mirrors, neutral density filters, and general purpose laboratory mirrors. Metals commonly deposited at ZC&R include aluminum, chromium, silver, gold, and Inconel.

Enhanced First Surface Aluminum

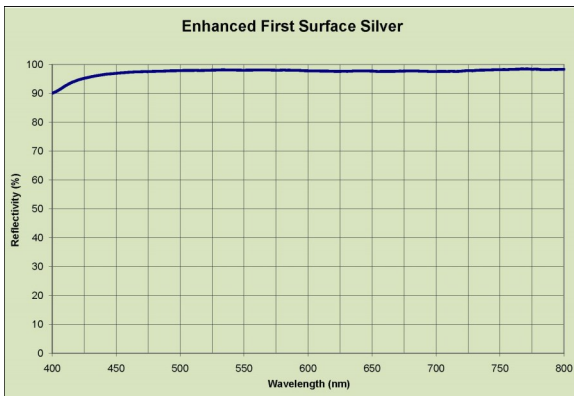
The front surface of the enhanced aluminum mirror coating reflects an average of 93% over the visible spectrum (450-650nm).



Back surface reflective aluminum coatings are also available.

Enhanced First Surface Silver

This design is very standard and often uses for demanding telescope and other very high performance imaging applications. Reflectance may be specified for IR wavelengths.

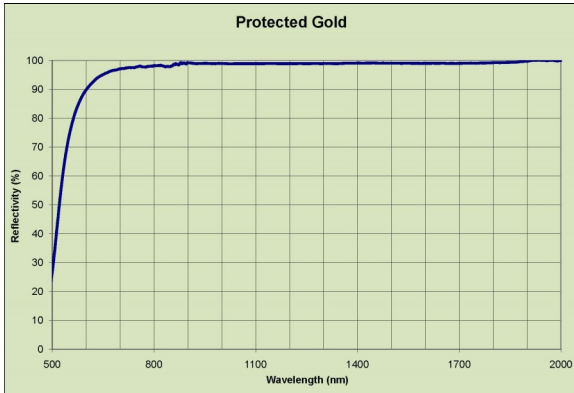


High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

Mirrors and Metals - *continued*



Protected Gold Mirror

The protected gold mirror coating reflects an average of 97% over the spectrum (700-2000nm). This coating can also be used for IR wavelength bands 3-5nm and 8-12nm.

ZC&R has the ability to deposit a number of precious and non-precious metals. Below is a list of metals, semi-conductors, and alloys routinely provided for customer applications.

- Gold
- Silver
- Aluminum
- Nickel
- Chromium
- Copper
- Inconel
- Titanium
- Hafnium
- Tantalum
- Tungsten
- Silicon
- Germanium
- Molybdenum

High Performance Thin Film Optical Coatings Technical Capabilities

11/22

Coatings Capabilities

Neutral Density Filters and Dark Mirrors - There are some applications for which the light used is too intense. In those cases a filter is often needed to apply a reduction in the intensity of the light without influencing the spectral profile. These wavelength neutral filters are often specified in terms of their optical density. Optical density can be calculated by taking the negative of the log (base 10) of the transmittance. For example, an optical density of 0.5 would be equivalent to approximately 32% transmittance. An optical density of 1.0 would be equivalent to a transmittance of 10%. Standard neutral density filter designs are available for the UV, Visible, and IR bands and for a variety of optical density values.

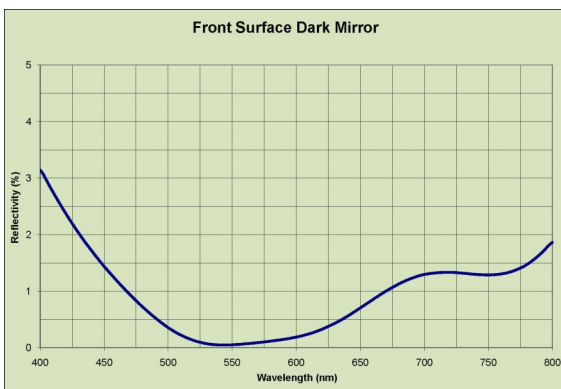
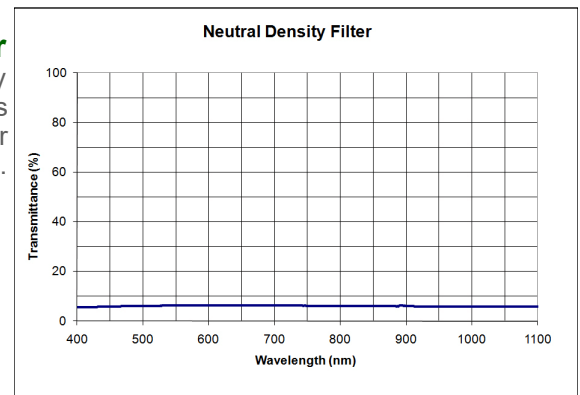
A similar optically significant case involves surfaces for which reflectance and transmittance are required to both be minimized over a narrow or broadband spectrum. This type of coating is commonly called a Dark Mirror due to the black non-reflective appearance. Dark mirror coatings are often used to reduce stray light reflections at surfaces intended to be opaque. A dark mirror coating can be applied to a variety of glass and metal substrate materials.

Specifications:

- Substrate:** Any glass substrate
- Thickness:** As thin as 70 microns and as thick as 6"
- Size:** Up to 24" in diameter, standard and custom up to 27" in diameter

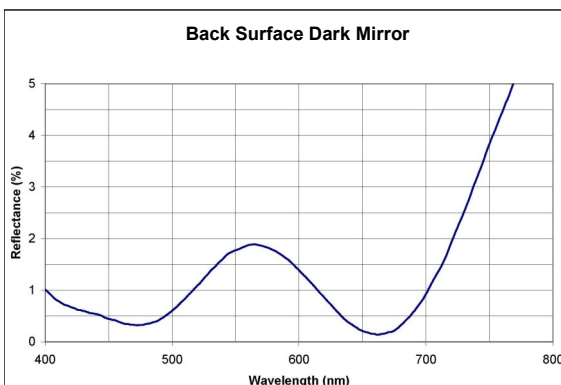
Neutral Density Filter

This neutral density filter example has an optical density of approximately 1.2 and a band average transmittance of $6.25 \pm 1.25\%$ for wavelengths 400-1100nm. Standard neutral density filter designs are also available for 12.5%, 25%, and 50% transmittance.



Dark Mirrors

It can be useful to separate Dark Mirror coatings into two groups: Front Surface and Back Surface. A front surface dark mirror design is one for which the reflectance is intended to be very low when viewed from the side coated. In contrast a back surface dark mirror design is intended to be viewed through the glass substrate. It is helpful to remember that a front surface dark mirror may be moderately or highly reflective when viewed from the back surface. And similarly a back surface dark mirror design may be quite reflective when viewed from the front surface.



You may have read the paragraph above and thought, "But wait! My application requires a dark mirror that has low reflectance for both the front and the back!" If so, we are glad to say you are in luck. ZC&R has extensive experience designing dark mirrors that can be used in both configurations simultaneously. This type of dark mirror allows your optic to be both opaque and dark when viewed from either side. Whatever type of dark mirror you require we look forward to reviewing your custom requirements and recommending the best solution.

High Performance Thin Film Optical Coatings Technical Capabilities

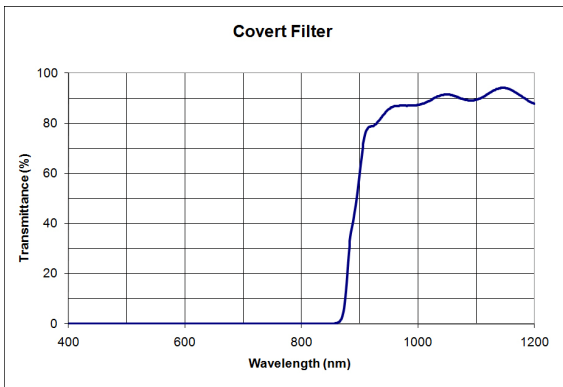
11/22

Coatings Capabilities

IR Filters (Covert, Semi-Covert, Blackeye) - Typically used with infrared cameras, scopes, and night vision goggles for surveillance, these filters enable infrared energy to be emitted from a variety of light sources while blocking visible energy, avoiding detection by the unaided eye.

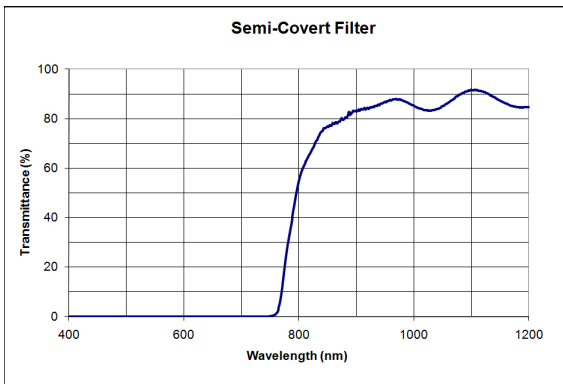
Specifications:

Substrate: Any glass substrate
Thickness: 1.1mm, 1.75mm, and 3.3mm
Size: Up to 24" in diameter



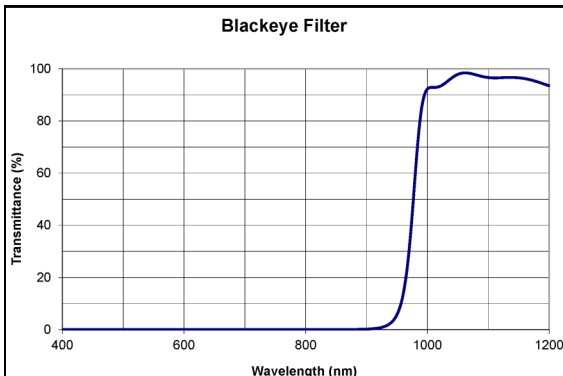
Covert Filter

This covert filter design blocks energy with wavelengths shorter than 825nm.



Semi-Covert Filter

This semi-covert filter design transmits more of the near infrared energy. These filters are used with imaging systems requiring greater sensitivity to wavelengths 800-900nm.



Blackeye Filter

This unique filter consists of a two piece optically coated substrate designed to block the visible output of a light source from as close as 3 feet. Transmittance is $\leq 1.0\%$ average from 400 to 890 nm and $\geq 65\%$ average from 950 to 2500nm. Reflectance is $\leq 5.0\%$ average from 400 to 700nm. It is ideally suited for use with night vision equipment or CCD cameras for short or long range surveillance applications.

High Performance Thin Film Optical Coatings

Glass Fabrication



Coating Deposition



CNC Machining



Strengthening - Chemical & Heat



Screen Printing of Graphics



Abrisa Technologies, a member of HEF Photonics, is a globally recognized technology glass fabrication and optical thin film coating company with expertise in high volume manufacturing and engineering capabilities, delivering Total Solutions that provide excellent performance, fitness-for-use and economies of scale.

Our US based, state-of-the-art ISO 9001:2015 and ITAR registered facilities include Abrisa Industrial Glass in Santa Paula, CA and ZC&R Coatings for Optics in Torrance CA. These two divisions produce solutions from cut-to-order coated glass components to custom complex and ready-to-install fabricated, strengthened, optically coated, electronically enabled and branded sub-assemblies.

Our Total Solutions serve a variety of markets including Micro-Electronics, Defense and Avionics, Display, Industrial Automation, Optical Sensors, Imaging, Photonics, Medical & Dental, Life Science and more.



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