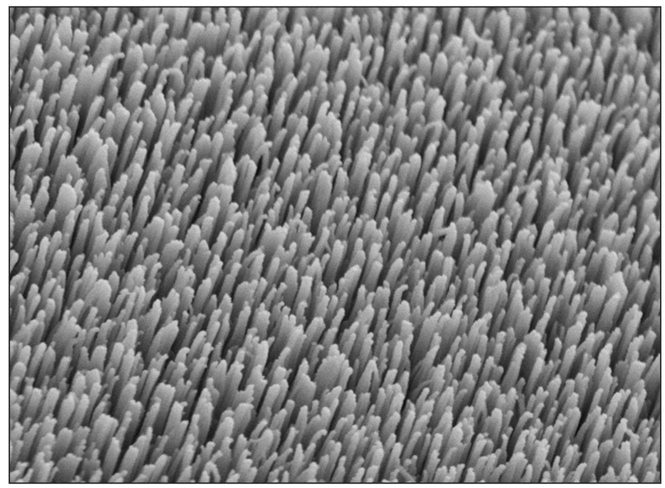
Textured Antireflective Surfaces for High-Power Applications

OVERVIEW

In applications using high-power lasers, antireflective (AR) optics are important to ensure that stray beams are minimized. However, traditional dielectric thin-film AR coatings can also present problems, as their laser damage threshold is typically lower than that of the optics themselves, limiting the power or intensity achievable in a given setup. In addition, as the number of optics in a system increases, the small reflections from AR coatings can compound, leading to problematic power loss.

Thorlabs' textured AR surfaces present an alternative to thin-film coatings with significantly higher laser damage thresholds. They also provide lower reflectance over a broader range of wavelengths and angles of incidence than is possible with thin-film coatings. As a result, replacing coated optics with textured optics in a high-power system can improve the performance and the robustness to damage during operation.

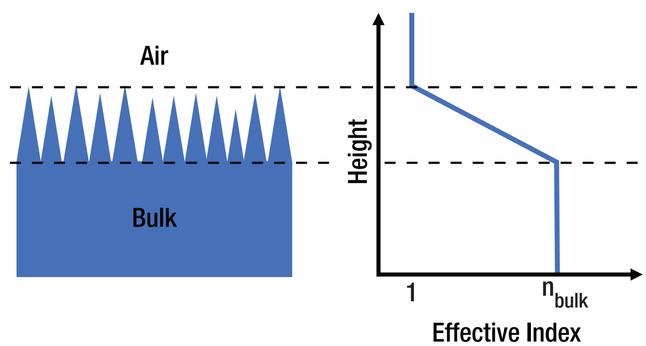
Low Broadband Reflectance | **High Laser Damage Threshold** | **Low Angular Sensitivity**



SEM image showing a top-view of a textured antireflection surface on a UV fused silica substrate.

TECHNOLOGY

Thorlabs' textured AR surfaces are created by removing material from the bulk optic substrate using a proprietary process, which has been optimized to fabricate subwavelength structures. The surface that remains consists of roughly conical nanostructures, with irregular spacing and varied height. These nanostructures produce a smooth gradient of the effective refractive index, as shown schematically in the figure to the right. Since there are no step changes in the refractive index, the incident light is able to travel from the air to the bulk glass and vice versa with virtually no Fresnel reflections. As a result, textured optics can achieve significantly higher transmission than un-textured optics and optics with traditional thin-film coatings.



The textured surfaces are made up of conical nanostructures that produce a continuous gradient in the effective index from air to the bulk material.

EXAMPLE: TEXTURED WINDOWS

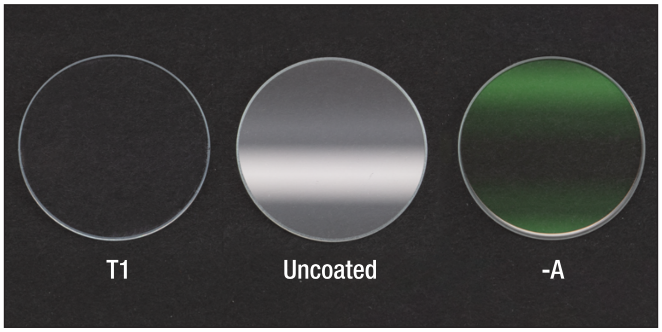
Thorlabs has developed a line of windows with textured antireflection surfaces, using UV fused silica (UVFS) or Infrasil®* as a substrate. UVFS windows with a TU or T1 textured surface exhibit antireflection performance from 230 nm to 450 nm or 400 nm to 1100 nm, respectively, while Infrasil windows with the T2 surface have antireflection performance from 1000 nm to 1700 nm. The table to the right shows the specifications for these surfaces. Our stock windows with these surfaces maintain ≥98% transmission across their spectral range.

Textured windows can also be created using different substrates and with surfaces designed for wavelength ranges from the UV to the IR.

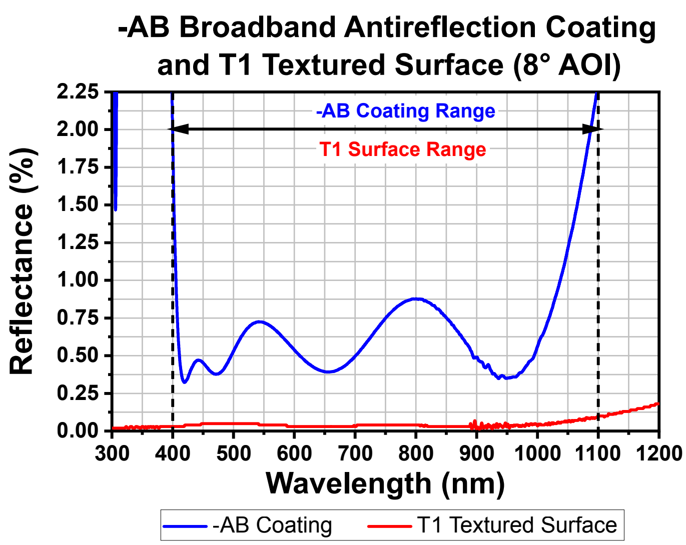
Surface Name	TU	T1	T2
Substrate	UV Fused Silica		Infrasil
Wavelength Range	230 - 450 nm	400 - 1100 nm	1000 - 1700 nm
Reflectance Over Wavelength Range[a]	R_{avg} < 0.25%		
Surface Quality[b]	10-5 Scratch-Dig		
Damage Threshold	>30 J/cm² at 355 nm, 10 ns, 10 Hz, Ø0.22 mm	>30 J/cm² at 532 nm, 10 ns, 10 Hz, Ø0.4 mm	>30 J/cm² at 1064 nm, 10 ns, 10 Hz, Ø0.23 mm

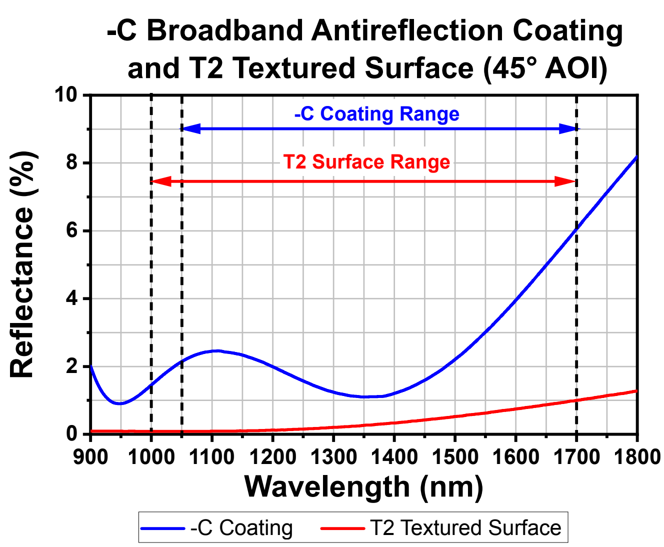
a. Specified at 0° Angle of Incidence
b. For Plano Surfaces

*Infrasil is a registered trademark of Heraeus Quarzglas



Visual comparison showing the superior antireflective performance of the T1 textured surface compared to uncoated and A-Coated (350 – 700 nm) UVFS windows. Each 1.0 mm thick window was exposed to fluorescent ceiling lights. Reflections from the surfaces of the uncoated and A-coated windows can be seen, whereas the textured window shows no visible reflections.





Comparison of the superior reflectance performance of Thorlabs' textured surfaces versus two thin-film AR coatings. Top: the T1 surface is compared to the -AB coating (400 – 1100 nm) at near-normal incidence. Bottom: the T2 surface is compared to the -C coating (1050 - 1700 nm) at a 45° angle of incidence.

Interested in textured antireflective surfaces for your application?

Email techsales@thorlabs.com for more information.

ANTIREFLECTION PERFORMANCE

Compared to traditional thin-film broadband antireflective (BBAR) coatings, textured surfaces exhibit lower reflectance over a very broad wavelength range and lower angular sensitivity. The antireflection properties of dielectric AR coatings are based on the interference between reflections from subsequent thin film dielectric layers. This behavior is highly dependent on the wavelength of the light, as the refractive indices and thicknesses of each layer are designed to provide the desired phase relationship between reflecting waves. Moreover, the angle of incidence (AOI) affects the effective thickness of each layer that the light interacts with, which leads to a strong dependence on the AOI.

In contrast, the effective index gradient of textured surfaces is less sensitive to the wavelength and AOI, allowing for very low reflectance over a broad range of both parameters. The image and graphs to the left demonstrate the superior antireflective performance offered by textured surfaces compared to three BBAR coatings.

DAMAGE THRESHOLD

The nanostructures comprising Thorlabs' textured surfaces are originally part of the bulk optic, and hence, they have substantially higher laser-induced damage thresholds than BBAR coatings. Laser-induced damage at moderate fluence typically originates from the interface between two materials, and the large number of thin-film layers in BBAR coatings increase the likelihood of damage. As textured surfaces consist of the same material as the bulk, their damage threshold is higher.

This provides an advantage in applications where high-power lasers are being used. In many setups, thin-film antireflective coatings can be the limiting factor for total power or beam size (which can cause increased space demands). In some applications, such as high-vacuum environments, optics cannot easily be replaced and damage to an optical coating can lead to other drawbacks.

As an example of the improved high-power capabilities, the T1 surface has a measured laser-induced damage threshold of >30 J/cm^2 for 10 ns pulses at 1064 nm, compared to >7.5 J/cm^2 for Thorlabs' -A coating (350 - 700 nm) on a UVFS substrate under the same conditions.

TEXTURED OPTICS

Textured surfaces can be created for a variety of glass substrates in addition to UVFS and Infrasil. Flat, concave, and convex textured surfaces can be created, allowing their use in a variety of optical elements such as windows, lenses, microscope slide covers, and glass cells for spectroscopy. Textured surfaces can also be incorporated into optical subsystems such as lens systems, microscope objectives, or any others where thin-film coatings are traditionally used.